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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—CIRCULAR No. 100.
L. O. HOWARD, Entomologist and Chief of Bureau.

# AN INDEX TO CIRCULARS 1 TO 100 OF THE BUREAU OF ENTOMOLOGY.

BY

ROLLA P. CURRIE AND ANDREW N. CAUDELL.

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CIRCULAR No. 100. Issued November 2, 1911.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

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# AN INDEX TO CIRCULARS 1 TO 100 OF THE BUREAU OF ENTOMOLOGY.

By ROLLA P. CURRIE and ANDREW N. CAUDELL.

The first circular of the present series, or what was formerly known as the second series, of the Bureau of Entomology was issued in 1891, while Circular 99 was issued in 1908. The circulars of the first series, something over 40 in number, were nearly all merely circular letters and had only a temporary value. Very few of these first-series circulars are now known to exist, and even the titles of most of them are now unknown.

While some of the circulars of the present, or second, series were in the nature of emergency circulars, and were therefore soon discontinued or superseded, yet very many others were popular summaries, containing in condensed form all the important data available concerning the particular insects discussed. They have therefore a distinct value to the student and worker in economic entomology as well as to the farmer, forester, horticulturist, and general reader. Many of the insects treated have not yet been made the subjects of bulletins or been considered in other publications of the department, and much information contained in these circulars is therefore not to be found elsewhere.

To make this information more easily available and to prevent it from being overlooked, the present index has been prepared, and it is hoped that it will be of use to all who read or consult the circulars of the bureau.

For convenience the index itself is preceded by a list of circulars 1 to 100, with their revisions. This list may be considered as complete and final, since the policy of issuing revised editions of circulars, i. e., under the original serial number, has been discontinued and no more such will be published.

Where circulars have gone through one or more revised editions the latest edition is the one indexed.

## LIST OF CIRCULARS 1 TO 100 OF THE BUREAU OF ENTOMOLOGY.

No. 1. Condensed information concerning some of the more important insecticides. pp. 7. May, 1891.

No. 2. The hop plant-louse [*Phorodon humuli* Schr.] and the remedies to be used against it. pp. 7, figs. 5, pl. 1. June, 1891.

No. 3. An important enemy to fruit trees. The San Jose scale [*Aspidiotus perniciosus* Comst.]: Its appearance in the eastern United States; measures to be taken to prevent its spread and to destroy it. By L. O. Howard. pp. 10, figs. 5. April 4, 1893.

No. 4. The army worm (*Leucania unipuncta* Haw.). By L. O. Howard. pp. 5, figs. 3. June 16, 1894.

No. 5. The carpet beetle or "Buffalo moth" (*Anthrenus scrophulariæ* L.). By L. O. Howard. pp. 4, fig. 1. September 8, 1894.

*Same*, revised edition. pp. 4, fig. 1. Issued August 10, 1908.

No. 6. The Mexican cotton-boll weevil (*Anthonomus grandis* Boh.). By L. O. Howard. pp. 5, figs. 3. April 2, 1895.

*Same*, Spanish edition. pp. 6, figs. 2. April 2, 1895.

No. 7. The pear-tree psylla (*Psylla pyricola* Foerst.). By C. L. Marlatt. pp. 8, figs. 6. May 1, 1895.

No. 8. The imported elm leaf-beetle (*Galerucella luteola* Müll.; *Galeruca xanthomelæna* Schrank). By C. L. Marlatt. pp. 4, fig. 1. May 23, 1895.

*Same*, revised edition. pp. 6, fig. 1. Issued September 22, 1908.

No. 9. Cankerworms [*Paleacrita vernata* Peck and (*Anisopteryx*) *Alsophila pometaria* Harr.]. By D. W. Coquillett. pp. 4, figs. 4. May 24, 1895.

No. 10. The Harlequin cabbage bug, or calico back (*Murgantia histrionica* Hahn). By L. O. Howard. pp. 2, fig. 1. May 24, 1895.

No. 11. The rose-chafer [*Macrodactylus subspinosus* Fab.]. By F. H. Chittenden. pp. 4, fig. 1. May 21, 1895.

*Same*, revised. pp. 4, fig. 1. Issued July 6, 1909.

No. 12. The Hessian fly (*Cecidomyia destructor* Say). By C. L. Marlatt. pp. 4. July 26, 1895.

*Same*, revised edition. pp. 4. April 13, 1900. (Superseded by No. 70.)

No. 13. Mosquitoes and fleas. By L. O. Howard. pp. 4. February 1, 1896.

*Same*, revised edition. November 15, 1897.

No. 14. (Revision of No. 6.) The Mexican cotton-boll weevil (*Anthonomus grandis* Boh.). By L. O. Howard. pp. 8, figs. 5. February 12, 1896.

*Same*, Spanish edition. pp. 8, figs. 5. May 18, 1896.

No. 15. General work against insects which defoliate shade trees in cities and towns. By L. O. Howard. pp. 4. March 6, 1896. (In advance from an article entitled "The shade-tree insect problem in the eastern United States," to be published in the Yearbook of the department for 1895.)

No. 16. The larger corn stalk-borer (*Diatræa saccharalis* Fab.). By L. O. Howard. pp. 3, figs. 3. August 13, 1896.

No. 17. The peach-tree borer (*Sannina exitiosa* Say). By C. L. Marlatt. pp. 4, fig. 1. September 30, 1896. (Superseded by No. 54.)

No. 18. (Revision of No. 14.) The Mexican cotton-boll weevil (*Anthonomus grandis* Boh.). By L. O. Howard. pp. 8, figs. 5. February 4, 1897.

*Same*, Spanish edition. pp. 10.
*Same*, German edition. pp. 11.
No. 19. The clover mite (*Bryobia pratensis* Garman). By C. L. Marlatt. pp. 4, fig. 1. March 5, 1897.
*Same*, second edition. pp. 4, fig. 1. July 19, 1897.
No. 20. The woolly aphis of the apple (*Schizoneura lanigera* Hausmann). By C. L. Marlatt. pp. 6, figs. 2. March 15, 1897.
*Same*, revised edition. pp. 6, figs. 2. June 23, 1908.
No. 21. The strawberry weevil (*Anthonomus signatus* Say). By F. H. Chittenden. pp. 7, figs. 4. March 18, 1897.
*Same*, revised edition. pp. 10, figs. 5. Issued September 19, 1908.
No. 22. The periodical cicada in 1897. By E. A. Schwarz. pp. 4. May 1, 1897.
No. 23. The buffalo tree-hopper (*Ceresa bubalus* Fab.). By C. L. Marlatt. pp. 4, figs. 2. May 10, 1897.
No. 24. The two-lined chestnut borer (*Agrilus bilineatus* Weber). By F. H. Chittenden. pp. 8, fig. 1. July 14, 1897.
*Same*, revised edition. pp. 7, fig. 1. Issued January 20, 1909.
No. 25. The ox warble (*Hypoderma lineata* Villers). By C. L. Marlatt. pp. 10, figs. 10. July 19, 1897.
No. 26. The pear slug (*Eriocampoides limacina* Retzius). By C. L. Marlatt. pp. 7, figs. 4. August 28, 1897.
No. 27. The Mexican cotton-boll weevil in 1897. By L. O. Howard. pp. 7. December 31, 1897.
No. 28. The box-elder plant-bug (*Leptocoris trivittatus* Say). By L. O. Howard. pp. 3, fig. 1. January 8, 1898.
No. 29. The fruit-tree bark-beetle (*Scolytus rugulosus* Ratz.). By F. H. Chittenden. pp. 8, figs. 5. March 25, 1898.
*Same*, revised edition. March 25, 1903.
No. 30. The periodical cicada in 1898. By E. A. Schwarz. pp. 3. April 1, 1898.
No. 31. The striped cucumber beetle (*Diabrotica vittata* Fab.). By F. H. Chittenden. pp. 7, figs. 2. April 26, 1898.
*Same*, revised edition. pp. 6, figs. 2. June 9, 1903.
*Same*, second revision. pp. 8, figs. 2. Issued May 22, 1909.
No. 32. The larger apple-tree borers. By F. H. Chittenden. pp. 12, figs. 3. July 1, 1898.
*Same*, revised edition. pp. 12, figs. 3. August 30, 1902.
*Same*, second revise. pp. 11, figs. 3. April 8, 1905.
*Same*, third revise. pp. 11, figs. 3. Issued December 10, 1907.
No. 33. Remedial work against the Mexican cotton-boll weevil. By L. O. Howard. pp. 6. July 1, 1898. (Supplementary to circulars 18 and 27.)
No. 34. House ants (*Monomorium pharaonis* et al.). By C. L. Marlatt. pp. 4, figs. 3. July 6, 1898.
*Same*, revise. pp. 4, figs. 3. Issued June 12, 1907.
No. 35. House flies (*Musca domestica* et al.). By L. O. Howard. pp. 8, figs. 6. July 11, 1898. (Superseded by No. 71.)
No. 36. The true clothes moths (*Tinea pellionella* et al.). By C. L. Marlatt. pp. 8, figs. 3. July 18, 1898.
*Same*, revise. pp. 8, figs. 3. Issued January 15, 1908.
No. 37. The use of hydrocyanic-acid gas for fumigating greenhouses and cold frames. By Albert F. Woods and P. H. Dorsett. pp. 10, figs. 3. January 10, 1899.
*Same*, corrected print. (Compare page 8.) pp. 10, figs. 3. January 10, 1899.
*Same*, revised edition. pp. 10, figs. 3. October 2, 1903.
*Same*, second revise. pp. 11, figs. 3. Issued April 3, 1908.

No. 38. The squash-vine borer (*Melittia satyriniformis* Hbn.). By F. H. Chittenden. pp. 6, figs. 2. April 22, 1899.

*Same*, revised edition. pp. 6, figs. 2. November 19, 1903.

*Same*, second revise. pp. 6, figs. 2. Issued September 3, 1908.

No. 39. The common squash bug (*Anasa tristis* De G.). By F. H. Chittenden. pp. 5, figs. 3. May 5, 1899.

*Same*, revised edition. pp. 5, figs. 3. March 23, 1905.

*Same*, second revise. pp. 5, figs. 3. Issued July 28, 1908.

No. 40. How to distinguish the different mosquitoes of North America. By L. O. Howard (with "Synoptic tables of the North American mosquitoes," by D. W. Coquillett). pp. 8, figs. 3. February 20, 1900.

No. 41. Regulations of foreign governments regarding importation of American plants, trees, and fruits. By L. O. Howard. pp. 4. August 24, 1900.

No. 42. How to control the San Jose scale. By C. L. Marlatt. pp. 6. October 22, 1900.

*Same*, revised. pp. 6. May 17, 1902.

*Same*, second edition. May 26, 1902.

*Same*, third edition. April 6, 1903.

*Same*, fourth edition. pp. 8. March 10, 1906.

*Same*, fifth edition. pp. 7. [March 31] 1909.

No. 43. The destructive green pea louse (*Nectarophora destructor* Johns.). By F. H. Chittenden. pp. 8, figs. 3. May 23, 1901.

*Same*, second edition [entitled "The pea aphis (*Macrosiphum pisi* Kalt.)"]. pp. 10, figs. 7. Issued February 25, 1909.

No. 44. The periodical cicada in 1902. By W. D. Hunter. pp. 4, figs. 2. March 13, 1902.

No. 45. A new nomenclature for the broods of the periodical cicada. By C. L. Marlatt. pp. 8. May 1, 1902.

No. 46. Hydrocyanic-acid gas against household insects. By L. O. Howard. pp. 6. June 22, 1902.

*Same*, revised edition. pp. 7. Issued February 20, 1907. Revised by C. L. Marlatt.

No. 47. The bedbug (*Cimex lectularius* Linn.). By C. L. Marlatt. pp. 8, figs. 3. June 15, 1902.

*Same*, revised edition. pp. 8, figs. 3. Issued February 26, 1907.

No. 48. The house centipede (*Scutigera forceps* Raf.). By C. L. Marlatt. pp. 4, figs. 2. June 10, 1902.

No. 49. The silver fish (*Lepisma saccharina* Linn.). By C. L. Marlatt. pp. 4, figs. 2. June 20, 1902.

No. 50. The white ant (*Termes flavipes* Koll.). By C. L. Marlatt. pp. 8, figs. 4. June 30, 1902.

*Same*, revised edition. pp. 8, figs. 4. Issued January 27, 1908.

No. 51. Cockroaches. By C. L. Marlatt. pp. 15, figs. 5. June 23, 1902.

*Same*, revised. pp. 14, figs. 5. Issued June 23, 1908.

No. 52. The lime, sulphur, and salt wash. By C. L. Marlatt. pp. 8. February 20, 1903.

*Same*, second edition. March 18, 1904.

No. 53. The yellow-winged locust (*Camnula pellucida* Scudd.). By C. B. Simpson. pp. 3, fig. 1. May 12, 1903.

No. 54. The peach-tree borer (*Sannina exitiosa* Say). By C. L. Marlatt. pp. 6, fig. 1. October 19, 1903.

No. 55. Powder-post injury to seasoned wood products. By A. D. Hopkins. pp. 5, fig. 1. November 20, 1903.

No. 56. The most important step in the cultural system of controlling the boll weevil. By W. D. Hunter. pp. 7. October 10, 1904. (Superseded by No. 95.)

No. 57. The greenhouse white fly (*Aleyrodes vaporariorum* Westw.). By A. W. Morrill. pp. 9, fig. 1. February 15, 1905.
No. 58. Report on the gypsy moth and the brown-tail moth, July, 1904. By C. L. Marlatt. pp. 12, pl. 1, map 1. March 21, 1905.
No. 59. The corn root-worms. By F. H. Chittenden. pp. 8, figs. 3. March 23, 1905.
No. 60. The imported cabbage worm (*Pontia rapæ* Linn.). By F. H. Chittenden. pp. 8, figs. 6. April 28, 1905.
No. 61. Black check in western hemlock. By H. E. Burke. pp. 10, figs. 5. May 24, 1905.
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No. 64. The cottony maple scale (*Pulvinaria innumerabilis* Rathvon). By J. G. Sanders. pp. 6, figs. 4. September 7, 1905.
No. 65. The cotton red spider (*Tetranychus gloveri* Bks.). By E. S. G. Titus. pp. 5, figs. 2. October 30, 1905.
No. 66. The joint-worm (*Isosoma tritici* Fitch). By F. M. Webster. pp. 5, figs. 5, October 20, 1905.
*Same*, revised edition. pp. 7, figs. 6. Issued September 21, 1908.
No. 67. The clover root-borer (*Hylastinus obscurus* Marsham). By F. M. Webster. pp. 5, figs. 4. December 28, 1905.
No. 68. The tobacco thrips and remedies to prevent "white veins" in wrapper tobacco (*Euthrips nicotianæ* Hinds). By W. A. Hooker. pp. 5, figs. 2. February 26, 1906.
No. 69. Some insects affecting the production of red clover seed. By F. M. Webster. pp. 9, figs. 8. April 12, 1906.
No. 70. The Hessian fly (*Mayetiola* [*Cecidomyia*] *destructor* Say). By F. M. Webster. pp. 16, figs. 16. April 14, 1906.
No. 71. (Revision of Circular No. 35.) House flies (*Musca domestica* et al.). By L. O. Howard. pp. 9, figs. 9. March 27, 1906.
*Same*, revised edition. pp. 10, figs. 9. September 21, 1906.
No. 72. Key to the known larvæ of the mosquitoes of the United States. By Harrison G. Dyar. pp. 6, fig. 1. April 27, 1906.
No. 73. The plum curculio (*Conotrachelus nenuphar* Herbst). By Fred Johnson and A. A. Girault. pp. 10, figs. 5. April 14, 1906.
No. 74. The periodical cicada in 1906. By C. L. Marlatt. pp. 5, figs. 3. April 16, 1906.
No. 75. Requirements to be complied with by nurserymen or others who make interstate shipments of nursery stock. By A. F. Burgess. pp. 6. July 5, 1906.
*Same*, revised edition. pp. 7. Issued July 24, 1908.
*Same*, second revision. pp. 9. Issued August 7, 1909.
No. 76. List of publications of the Bureau of Entomology. Compiled by Mabel Colcord. pp. 21. September 24, 1906.
*Same*, revised to March 1, 1908. pp. 28.
*Same*, revised to May 1, 1909. pp. 29.
*Same*, revised to February 1, 1910. pp. 32.
No. 77. Harvest mites, or "chiggers." By F. H. Chittenden. pp. 6, figs. 3. September 29, 1906.
No. 78. The slender seed-corn ground-beetle (*Clivina impressifrons* Lec.). By F. M. Webster. pp. 5, figs. 2. October 4, 1906.
No. 79. The brood diseases of bees. By E. F. Phillips. pp. 5. October 3, 1906.

No. 80. The melon aphis (*Aphis gossypii* Glov.). By F. H. Chittenden. pp. 16, figs. 6. November 14, 1906.

No. 81. The aphides affecting the apple. By A. L. Quaintance. pp. 10, figs. 8. Issued March 9, 1907.

No. 82. Pinhole injury to girdled cypress in the South Atlantic and Gulf States. By A. D. Hopkins. pp. 4, fig. 1. Issued January 2, 1907.

No. 83. The locust borer [*Cyllene robiniæ* Forst.] and methods for its control. By A. D. Hopkins. pp. 8, figs. 4. Issued February 19, 1907.

No. 84. The grasshopper problem and alfalfa culture. By F. M. Webster. pp. 10, figs. 8. Issued April 6, 1907.

No. 85. The spring grain-aphis (*Toxoptera graminum* Rond.). By F. M. Webster. pp. 7, figs. 3. Issued March 29, 1907. (See also No. 93.)

No. 86. The corn leaf-aphis [*Aphis maidis* Fitch] and corn root-aphis [*Aphis maidiradicis* Forbes]. By F. M. Webster. pp. 13, figs. 4. Issued May 6, 1907.

No. 87. The Colorado potato beetle (*Leptinotarsa decemlineata* Say). By F. H. Chittenden. pp. 15, figs. 6. Issued June 3, 1907.

No. 88. The terrapin scale (*Eulecanium nigrofasciatum* Pergande). By J. G. Sanders. pp. 4, figs. 3. Issued May 14, 1907.

No. 89. The periodical cicada in 1907 (*Tibicen septendecim* L., race *tredecim* Walsh-Riley). By C. L. Marlatt. pp. 4, figs. 3. Issued May 14, 1907.

No. 90. The white-pine weevil [*Pissodes strobi* Peck]. By A. D. Hopkins. pp. 8, figs 6. Issued June 18, 1907.

No. 91. Note on the occurrence of the North American fever tick [(*Boophilus*) *Margaropus annulatus* Say] on sheep. By W. D. Hunter. pp. 3. Issued July 3, 1907.

No. 92. Mites and lice on poultry. By Nathan Banks. pp. 8, figs. 6. Issued September 25, 1907.

No. 93. The spring grain-aphis or so-called "green bug" (*Toxoptera graminum* Rond.). By F. M. Webster. pp. 18, figs. 7. Issued August 22, 1907.

*Same*, revised. pp. 22, figs. 10. Issued June 23, 1909.

No. 94. The cause of American foul brood [*Bacillus larvæ*]. By G. F. White. pp. 4. Issued July 29, 1907.

No. 95. (Revision of Circular No. 56.) The most important step in the control of the boll weevil [*Anthonomus grandis* Boh.]. By W. D. Hunter. pp. 8. Issued October 3, 1907.

*Same*, revised edition. pp. 8. Issued September 21, 1908.

*Same*, French edition. pp. 11. Issued January 21, 1909.

No. 96. The catalpa sphinx (*Ceratomia catalpæ* Bdv.). By L. O. Howard and F. H. Chittenden. pp. 7, figs. 2. Issued December 16, 1907.

No. 97. The bagworm (*Thyridopteryx ephemeræformis* Haw.). By L. O. Howard and F. H. Chittenden. pp. 10, figs. 11. Issued February 6, 1908.

No. 98. The apple-tree tent caterpillar (*Malacosoma americana* Fab.). By A. L. Quaintance. pp. 8, figs. 4. Issued January 28, 1908.

No. 99. The nut weevils. By F. H. Chittenden. pp. 15, figs. 14. Issued March 6, 1908.

No. 100. An index to Circulars 1 to 100 of the Bureau of Entomology. By Rolla P. Currie and Andrew N. Caudell. pp. i–ii, 1–49. Issued October —, 1911.

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## I.

CIRCULAR No. 101. Issued May 4, 1908.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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## THE APPLE MAGGOT OR "RAILROAD WORM."

(*Rhagoletis* [*Trypeta*] *pomonella* Walsh.)

By A. L. QUAINTANCE,

*In Charge of Deciduous Fruit Insect Investigations.*

Five important insect pests injure the fruit of the apple in the United States, namely, the codling moth (*Carpocapsa pomonella* L.), the lesser apple worm (*Enarmonia prunivora* Walsh), the plum curculio (*Conotrachelus nenuphar* Hbst.), the apple curculio (*Anthonomus quadrigibbus* Say), and the species under consideration.

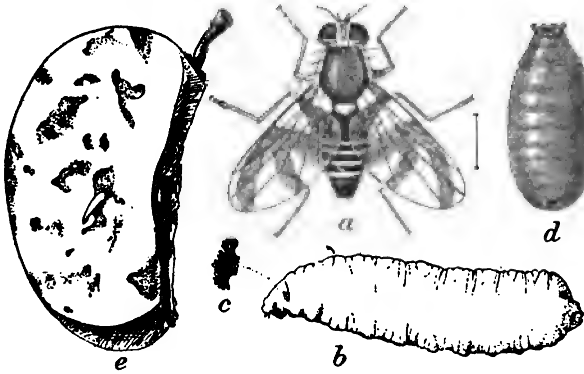


FIG. 1.—Apple maggot (*Rhagoletis pomonella*): *a*, Adult; *b*, larva or maggot; *c*, funnel of cephalic spiracle; *d*, puparium; *e*, portion of apple showing injury by maggots. *a*, *b*, and *d*, Enlarged; *c*, still more enlarged; *e*, reduced. (Original.)

The apple maggot, as the name implies, is the larva of a fly or dipterous insect, and belongs to the family Trypetidæ, which group contains numerous other fruit-infesting maggots,[a] some of them very serious pests, and, from their structure, mode of life, and feeding habits, very difficult of control. Apples injured or "railroaded" by the apple maggot show discolored winding burrows, or tracks, and

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[a] *Anastrepha* (*Trypeta*) *ludens* Loew., the so-called Mexican orange worm, is an enemy of oranges in portions of Mexico, infesting also the guava and mango, and *A. acidusa* Walk. infests the peach in the same country. *Rhagoletis ribicola* Doane infests currants and gooseberries in the United States, as does also *Epochra canadensis* Loew. *R. cingulata* Loew has recently been found to be a cherry pest in this country, working in a way similar to the European cherry fly, *Trypeta cerasi* L. (*signata* Meig.). *Ceratitis capitata* Wied., the so-

cavities here and there in the flesh, and when infested with several larvæ the pulp will be usually quite honeycombed with their burrows and more or less broken down into a yellowish mass, merely held together by the skin. (See fig. 1, *e.*)

DISTRIBUTION AND DESTRUCTIVENESS.

The apple maggot is a native American species, its natural food being haws (Cratægus), and in at least one instance it has been bred from crab-apples. Its feeding upon cultivated apples is thus an acquired habit, and although the insect has been reported from widely separated points in the central and eastern States, indicating its possible general distribution, for some reason it does not attack the apple throughout its range, but only in certain localities and portions of the country. This circumstance is a fortunate one for the apple grower, and from a scientific standpoint is of much interest. Walsh thought it might be explained on the supposition of the development in the New England States, where its injuries to apples were first noticed, of a race of apple-infesting individuals, the descendants of which, with the acquired habit, have been gradually distributed to other localities.

The apple maggot was described by Walsh in the American Journal of Horticulture for December, 1867, pages 338–343, and also in the First Report of the Acting State Entomologist of Illinois, from flies from eastern apples and from Illinois haws. Adult specimens from this latter fruit had been secured by him some five or six years earlier, and in July, 1867, he reared flies from maggots infesting apples from Connecticut, Massachusetts, and New York, and conclusively showed the identity of the insects infesting haws in Illinois with those infesting apples in the northeastern part of the United States. In the New England States mentioned, however, the species had been noted as an enemy of apple for some years before the time of Walsh's description. By 1866 it was common in the Hudson River country, at North Hempstead, Long Island, in the Oneida community in New York State, at East Falmouth, Mass., and probably in Vermont, and it occurred in Connecticut.[a]

called Mediterranean fruit fly, or Bermuda peach maggot, is widely distributed, infesting a considerable variety of soft fruits, as oranges, peaches, plums, pineapples, and bananas, but fortunately has not yet been introduced into the United States. In Europe *Tephritis onoperdinis* Fab. injures celery, and *T. tryoni* Froggatt seriously infests, in portions of Australia, bananas, peaches, oranges, etc., and another species of this genus (*psidi* Froggatt) in that country infests guavas. *Trypeta musæ* Froggatt seriously injures bananas in the New Hebrides. Some of these species are very general feeders, and the greatest care should be exercised, especially in the case of the Bermuda peach maggot, that they be not introduced into the United States.

[a] First Rept. Acting State Ent. Illinois, pp. 29–33 (1867).

In 1881 the apple maggot was reported by Professor Comstock [a] from Ithaca, N. Y., in apples, and was bred by him from Cratægus at Washington, D. C. Professor Cook,[b] in 1884, received specimens from Delavan, Wis., where it was reported as doing very great injury, and the year following, the insect was the cause of considerable loss in Ingham and adjoining counties in Michigan.

Lintner,[c] in 1885, gives the additional localities of North Ashburnham, Mass., Franklin and Schenectady, N. Y., and Brandon, Vt. Its introduction into Maine, as stated by Professor Harvey,[d] occurred prior to 1882, by which time it had become well established, and by 1899 occurred quite generally over the State. Its occurrence at Montclair, N. J., was recorded in 1889 by Mr. E. Williams, in Garden and Forest, page 527, and this locality is also given for the apple maggot by Dr. J. B. Smith in his list of insects of New Jersey, page 687 (1899).

In 1894 Doctor Howard [e] records the occurrence of the apple maggot from Waynesville, N. C., and Doctor Fletcher [f] records its first appearance in Canada, August 31, 1896, in apples from Adolphustown, Ontario. As stated by Professor Lochhead,[g] it had become quite injurious by 1902, more than one-half of the crop having been destroyed in some orchards in Prince Edward County. Professor Osborn,[h] on the authority of Professor Hine, records its occurrence in northwestern Ohio in 1904, and states that injured fruit comes on the market at Columbus, though perhaps from outside of the State. Doctor Chittenden [i] notes that the apple maggot was unusually injurious in Ohio in 1903. By 1905 the insect had extended its range in Canada, as shown by the records of Doctor Fletcher [j] of its occurrence at Como and St. Hilaire, Quebec. The apple maggot is recorded from Minnesota by Professor Washburn,[k] and the records of the Bureau of Entomology show the additional localities of Dyberry, Pa., and Douglas, Mich.

Numerous records of this Bureau, as well as published accounts, show that the insect is generally distributed throughout the greater part of the New England States, and that it is a very destructive

[a] Rept. Ent. U. S. Dept. Agric., 1881–82, p. 196.

[b] Rept. Mich. Hort. Soc., 1884, p. 200.

[c] Second Report N. Y. State Ent., p. 121 (1885).

[d] Ann. Rept. Maine State Coll. Agr. Exp. Sta., 1889, Pt. III, pp. 190–241.

[e] Insect Life, VII, p. 279.

[f] Rept. Ent. and Bot. Exp. Farms Canada for 1896, p. 257 (1897).

[g] 33rd Ann. Rept. Ent. Soc. Ont., p. 67, 1902 (1903).

[h] Bul. 46, Div. Ent. U. S. Dept. Agric., p. 88 (1904).

[i] Yearbook, U. S. Dept. Agric. for 1903, p. 563.

[j] Rept. Ent. and Bot. Exp. Farms of Canada for 1904, p. 238 (1905).

[k] Bul. 93, Minn. Agric. Exp. Sta., p. 118 (1905).

enemy to apples. The flies do not spread rapidly, and hence individual orchards or certain varieties of apples may suffer severely, while those adjoining may be little injured. Although the pest was bred from haws, in 1867, in Illinois, there has been but one record of its infesting apples in that State.[a]

### FOOD PLANTS.

The natural food of the apple maggot is wild haw (Cratægus), and probably several species are infested. It was bred from haws by Walsh in Illinois, by Cook in Illinois and Wisconsin, and by Comstock at Washington, D. C. Despite its supposed general occurrence in the fruit of this plant, no further records of breeding from haws have been found, and Professor Harvey states that it was not found in haws in Maine. During the past three years the Bureau of Entomology has collected or received fruit of *Cratægus* spp. from various parts of the country, but has not observed it to be infested with the apple maggot in any instance, and it appears quite doubtful if the distribution of the species is as general as is that of its native food plants.

The early statements of the probable feeding of this species on crab-apple appear not to have been based on actual observations, and aside from Riley's record of its occurrence on crabs,[b] no definite data have been presented to show that it infests this fruit. Professor Harvey thought it improbable that this fruit would be used, for the reason that it is quite green and hard during the period of flight and oviposition of the flies. The insect was found infesting plums and late cherries in northern Michigan, by Professor Cook,[c] in 1889, though no additional records of its occurrence in these fruits have been seen.

Of apples, sweet and subacid summer varieties are worst attacked, but fall and winter sorts are also infested, including distinctly acid varieties. Professor Harvey has prepared a list of apples showing their relative degree of infestation as observed by him in Maine during his careful study of the apple maggot.[d]

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[a] Cordley, Orchard and Garden, 1889, p. 192.
[b] Am. Agric., 1872, p. 263.
[c] Second Ann. Rept. Mich. Agric. Exp. Sta., p. 153.
[d] Loc. cit.

*Varieties of apples known to be affected by Rhagoletis (Trypeta) pomonella.*[a]

| Variety. | Flavor. | | | Time of maturity. | Remarks. |
|---|---|---|---|---|---|
| | Sweet. | Sub-acid. | Acid. | | |
| Alexander | | | + | Autumn | Sparingly infested. |
| Bullock (Am. Golden Russet) | | | | Winter | Do. |
| Bailey Sweet | + | | | do | Do. |
| Baldwin | | | + | do | Do. |
| Benoni | | + | | Autumn | Badly infested. |
| Bough | + | | | Summer | Do. |
| Canada Baldwin | | | + | Winter | Sparingly infested. |
| Catshead | | + | | Autumn | Do. |
| Chenango | | + | | do | Badly infested. |
| Colvert | | + | | do | Sparingly infested. |
| Danvers | + | | | Winter | Do. |
| Dayton | | + | | do | Do. |
| Derby Pippin | | + | | do | Do. |
| Diana | | + | | Autumn | Do. |
| Early Harvest | | + | | | Badly infested. |
| Esopus (Esopus Spitzenburg) | | + | | Winter | Do. |
| Fall Jenneting | | + | | Autumn | Do. |
| Fall Pippin | | + | | do | Sparingly infested. |
| Fameuse | | + | | Winter | Do. |
| Franklin Sweet | + | | | Autumn | Badly infested. |
| Garden Royal | | + | | do | Do. |
| Golden Ball | | + | | Winter | Sparingly infested. |
| Golden Russet | | + | | do | Do. |
| Gravenstein | | + | | do | Badly infested. |
| Grimes | | + | | do | Sparingly infested. |
| Hightop Sweet | + | | | Autumn | Badly infested. |
| Hubbardston | | + | | Winter | Sparingly infested. |
| Hurlbut | | + | | Autumn | Badly infested. |
| Irish Peach | | + | | do | Sparingly infested. |
| Jewett Red | | + | | Winter | Badly infested. |
| King Sweet | + | | | Summer | Do. |
| Lady Sweet | + | | | Winter | Sparingly infested. |
| Maiden Blush | + | | | Autumn | Do. |
| Mexico | + | | | do | Do. |
| Mother | | + | | Winter | Badly infested. |
| Munson | + | | | Summer | Do. |
| New York Sweet | + | | | do | Do. |
| Northern Spy | | + | | Winter | Do. |
| Oldenburg (Duchess) | | | + | Autumn | Sparingly infested. |
| Paradise Sweet | + | | | Winter | Badly infested. |
| Pearmain (?) | | + | | do | Do. |
| Pewaukee (?) | | + | | do | Sparingly infested. |
| Porter | | + | | Autumn | Badly infested. |
| Pound Sweet | + | | | Winter | Sparingly infested. |
| Primate | | + | | Summer | Do. |
| Pumpkin Sweet | + | | | Autumn | Badly infested. |
| Ramsdell | + | | | Winter | Sparingly infested. |
| Red Astrachan | | + | | Summer | Badly infested. |
| Rhode Island Greening | | | + | Winter | Sparingly infested. |
| Ribston | | | | do | Do. |
| Rolfe | | + | | do | Do. |
| Russell | | + | | | Badly infested. |
| Snow | | + | | Autumn | Do. |
| Somerset | | + | | do | Sparingly infested. |
| Sops of Wine | | + | | Summer | Badly infested. |
| Tetofski | + | | | do | Do. |
| Tolman | + | | | Winter | Do. |
| Tompkins King | | + | | do | Sparingly infested. |
| Twenty Ounce | | + | | Autumn | |
| Wagener | | + | | Winter | |
| Wealthy | | + | | do | Badly infested. |
| Westfield (Seek-no-further) | | + | | do | |
| Williams | | + | | Summer | Do. |
| Winthrop Greening | | | + | Autumn | Do. |
| Yellow Bellflower | | + | | Winter | Do. |

[a] Names of varieties of apples have been corrected to agree with those given in "Nomenclature of the Apple," by W. H. Ragan. Bul. 56, Bur. Plant Industry, U. S. Dept. Agric. (1905).

The susceptibility to injury of the respective varieties mentioned, as observed in Maine, would not necessarily be true for other regions, but the list will serve to show that all classes of fruit are subject to

attack. As a general statement, it may be said that the insect will be most destructive to summer and fall varieties, or to those varieties which are ripe or are approaching maturity during the period of principal activity of the flies.

### HOW THE INSECT SPREADS.

It is not known whether the apple maggot has spread from the New England States, where its injuries were first noticed, to the several localities where its presence has been observed—as in Ohio, Wisconsin, Michigan, North Carolina, etc.—or whether the insect, already present on haws, simply turned its attention to apples. The former view, however, appears the more probable, and its spread would have been readily brought about by the introduction of infested apples. In regions where the insect occurs in apples, a considerable amount of infested fruit will be barreled, the larvæ later deserting the fruit and forming puparia on the bottom of the barrel. In the ordinary course of commerce the insect would thus be introduced into new localities, often quite remote. In view of the extent of apple production in the territory which has long been infested with this species (i. e., the New England States), and the consequent almost certain dissemination of the apple maggot to various parts of the country, it is cause for much surprise that the insect is not much more generally and widely established as an apple pest. It is very probable that the insect has been introduced into most of the apple-growing regions in the United States and also into those of Europe and the Colonies, but for some reason has not established itself. Thus the insect has been frequently found in apples on the markets in Washington, D. C., though there is no evidence to indicate that it has become established in orchards in that vicinity.

When once established in an orchard, its spread fortunately is usually very slow. It may confine its attack to a single tree, for two or three years, before spreading to adjacent trees of the same or other varieties equally subject to attack; and varieties seriously infested in one orchard may be exempt in another. The slowness of its spread from tree to tree and from one orchard to another has been commented upon by numerous workers.

The flies in their habits are exceedingly local, apparently confining their attention to the trees upon which the previous generation developed—in marked distinction to the spreading habits of many other insects. This habit is a very fortunate one for the fruit grower, and is of much practical importance in control, permitting great reduction and possible extermination of the pests when infestation is limited to but a few trees, and especially in localities but recently invaded.

DESCRIPTION.

*Egg.*—The eggs of the apple maggot are quite small, varying from 0.8 to 0.9 mm. in length by 0.2 to 0.25 mm. in width, fusiform, and light yellow in color as taken from the fruit. A short, broad pedicel, about one-twentieth the length of the egg, is found at the broader end, which end is darker and pitted with irregular hexagonal cells with raised lacerated borders for about one-fourth the length of the egg. (See fig. 2, *a.*)

*Larva.*—The larva (fig. 1, *b*) is footless, and when full grown is from 7 to 8 mm. long, with a width of from 1.75 to 2 mm., yellowish-

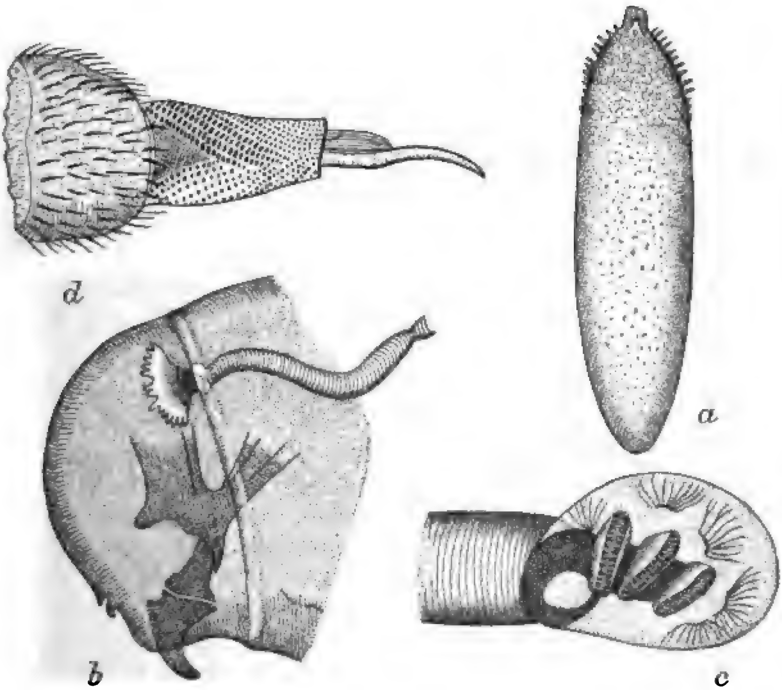


FIG. 2.—*Rhagoletis pomonella*: *a*, Egg; *b*, head of larva, showing chitinous hooks and framework within the head, and funnel-shaped spiracle; *c*, caudal spiracle; *d*, ovipositor, with which eggs are placed beneath skin of apple. All greatly enlarged. (*b, c*, After Comstock; *a, d*, after Harvey.)

white in color, at times tinged with greenish. The body is composed of 14 segments, widest across the ninth, tenth, and eleventh, and sloping gradually backward, and more rapidly toward the head end. The caudal end is truncate, and on the lower portion of the anterior end (first segment) is a pair of black, curved, parallel hooks, attached to a chitinous framework within the head, the hooks being used to rasp the pulp in the liberation of juice for food. A pair of spiracles occurs on the dorsal surface on each side at the juncture of the first

and second segments (fig. 2, *b*) and a pair on the sloping surface of the caudal segment. The spiracles on the cephalic end have funnel-shaped mouths, the funnel being bordered with a double row of about 20 projections. The caudal spiracles each show 3 transverse slit-like openings and 4 groups of bristles. (See fig. 2, *c*.)

*Pupa.*—The pupa is a small, barrel-shaped structure, pale yellowish-brown in color, measuring about 4.2 to 5.2 mm. in length, with a width of from 2 to 2.6 mm. The larva in pupating does not shed its skin, but simply contracts, assuming an oval form, causing the cephalic spiracles to project in front as tubercles. Although the caudal end also shrinks, the spiracles are still visible, as are also the body segments of the larva. The true pupa is formed within the larval skin. (See fig. 1, *d*.)

*Adult.*—The parent of the apple maggot is a two-winged fly (fig. 1, *a*), somewhat smaller than the house fly, of a general black color, with yellowish head and legs, greenish eyes, and dark feet. In the male there are 3, and in the female 4 white bands across the abdomen. Across the wings of both sexes are 4 black bands as shown in the figure. The females are from 5 to 6 mm. in length, with a spread of wings of about 12.15 mm. The males are somewhat smaller.

## LIFE HISTORY AND HABITS.[a]

There is but one generation of the apple maggot each year, though the occurrence of maggots in the fruit during the summer and autumn, due to the great irregularity in time of appearance of the flies, is calculated to mislead those not familiar with the insect's life history. The time and appearance of the adults is thought to be influenced by the date of the ripening of the fruit which they infested the previous season, though this supposition has not been established. During an ordinary season in Maine, the flies will begin to appear and will be ovipositing about July 1, and earlier in the States to the south. By the middle of July, in Rhode Island, during an average season, as stated by Profs. F. W. Card and A. E. Stene, early varieties subject to attack will show many of the egg punctures of the females.

Flies have lived in confinement for three weeks, and out of doors the period is doubtless somewhat longer. The female makes punctures through the skin of the apple by means of her sharp ovipositor (fig. 2, *d*), inserting the eggs singly into the flesh in a vertical position. Oviposition may occur on any part of the fruit, though mostly on the side and especially on the paler portions, where the apple has

[a] The apple maggot was carefully investigated in Maine by the late Professor Harvey, and his Report (l. c.) has been largely the basis of the present article.

been protected from the sun by the foliage. An individual female is capable of producing from 300 to 400 eggs, egg laying continuing throughout her life. About one-half minute is occupied in the act of depositing a single egg, and the characteristic brownish speck left by the ovipositor can, upon close examination, be detected by the unaided eye, and resembles the brownish rusty spots occurring normally on some varieties. These egg punctures may be best observed, however, with a hand lens, and are then seen to be oblong or circular holes, with the surrounding border brownish and somewhat shrunken. In four or five days, under favorable conditions, the egg hatches and the minute footless maggot begins to feed on the pulp of the fruit. Although the larva is without true opposable jaws, it is provided with two hooks on the head above the mouth by which the pulp is rasped loose, the larva drawing into the mouth the juices thus liberated. The pulp which is not eaten soon turns brown and renders the burrows through the flesh more readily visible. The larva, in its feeding, channels here and there through the flesh, sometimes burrowing for a distance just under the skin, the brownish trail in light-skinned varieties appearing as a linear bruise.

The rate of development of the larvæ conforms to that of the fruit, and the larvæ do not mature until the fruit is ripe. Early appearing flies attack the summer varieties, and those appearing later infest fall and winter sorts. Their development is checked by cold, and they are apparently able to exist for a considerable time in a practically stationary condition until the maturity of the fruit permits of their further growth to maturity.

Apples at gathering time may show no exterior indications of infestation, yet when cut open will be found thoroughly burrowed and honeycombed by the larvæ; or the apparently sound mature fruit may be so infested with the small, inconspicuous larvæ and eggs that it may be soon destroyed after storing. The work of a single maggot will injure the value of the fruit, though a dozen or more may often be present. Under favorable conditions of temperature and in ripening fruit, the maggots will become full grown in four or five weeks. The larvæ mature as the fruit is ripe, and leave this after it has fallen to the ground, as no exit holes have been noticed in fruit on the trees. In deserting the fruit a hole is made through the skin and the larva burrows an inch or less below the surface of the soil, or on sod land probably pupates around the roots of the grass; or sometimes the pupal stage is entered on the surface of the ground under the decayed fruit. In fruit in barrels, in storehouses, etc., the larvæ pupate on the bottom of the receptacle, and the puparia are often very numerous in such places. The insect remains in the pupal stage

until the following summer, the adult fly appearing early or late, depending apparently on whether the larvæ infested summer, fall, or winter fruit.

### INSECTS WHICH MAY BE MISTAKEN FOR THE APPLE MAGGOT.

There will often be found in apples partly or wholly decayed, as from the work of the apple maggot or other causes, larvæ which might very readily be mistaken for those of the species under consideration. Principally the larvæ of two kinds of flies will thus be found, namely, the vine-loving pomace fly (*Drosophila ampelophila* Loew)—a small clear-winged, red-eyed fly—and the pretty pomace fly (*Drosophila amœna* Loew), similar to the former, but with black spots on the wings. These insects are of interest as likely to be mistaken for the apple maggot and hence the cause of needless alarm. They are of little economic importance, though undoubtedly hastening the decay of fruits.

### PREVENTIVE MEASURES.

The apple maggot has proved to be an unusually troublesome insect to combat successfully. The eggs are deposited beneath the skin of the fruit, within which also the larva feeds until full grown. The pupal stage is passed just under the soil, or around the roots of grass in sod land, and the flies do not feed in a way to permit of their destruction. Spraying with arsenicals, so effective against the codling moth or apple worm, is for this pest quite useless.

The insect, however, may be attacked in two important ways. As stated, the larvæ do not leave the fruit until the latter has ripened and fallen to the ground. The prompt gathering and destruction of the windfalls, before they are deserted by the maggots, would serve to keep the insects greatly reduced, amounting to practical extermination if thoroughly carried out. This practice has long been recommended by entomologists, and comprises the most effective measure of controlling the pest at present known. Greatest benefit will come from the practice when carried out uniformly by the orchardists of a community. Allowing the wormy fruit to decay on the ground is most favorable to multiplication of the apple maggot. Orchardists having this pest to contend with should arrange to destroy the infested fruit promptly after it falls, and this may be accomplished in whatever way is most practicable under individual conditions.

Picking up the fruit by hand will often prove feasible and can be done by children, but great care is necessary that the work be done thoroughly. The gatherings should be made daily if possible, or at least every two or three days. The fruit may be fed to stock, taking

care that any excess not at the moment needed be stored in tight boxes or receptacles so that any larvæ deserting the fruit will be forced to pupate on the bottom of the container, where later they may be destroyed. When the drop fruit is not needed for the stock, it may be simply thrown into a hole or holes here and there in the orchard, to be finally covered with 2 or 3 feet of earth in the late fall after frosts have occurred, to prevent the escape of flies the following season. The work of gathering need not be begun until the first ripe windfalls of the early varieties are found, but should be kept up from this time until all the fruit has been harvested.

Orchards may often be pastured with sheep, hogs, or cattle, in a way to insure the destruction of the windfalls, and this practice is recommended as the cheapest and most satisfactory method of dealing with the apple-maggot problem. Orchards may be permanently pastured or the stock turned in daily in sufficient numbers and at times to accomplish the desired consumption of the fallen fruit. This practice will be especially useful in commercial orchards, and, where infestation from adjacent orchards is not great, will insure practically clean fruit.

Plowing and cultivation of orchards would appear to be a useful practice in the control of this pest, and these methods have been more or less recommended for some years. Careful experiments in Rhode Island on the value of such work have recently been reported by Professors Card and Stene.[a] Puparia of apple maggots were placed at different depths in the soil, ranging from 1 to 6 inches, to approximate conditions resulting from plowing to bury the pupæ, but this was found to have little effect in preventing the escape of flies, and the conclusion was reached that spring plowing of orchards to turn under the pupæ was valueless, under the soil conditions which there obtained.

It is thought, however, that frequent tillage of the orchard in early summer may be unfavorable to the development of the pupæ to flies, and experiments made in 1904 by Messrs. Card and M. A. Blake[b] with pupæ placed in boxes in which the soil was frequently stirred, resulted apparently in their complete destruction. More extended and conclusive experiments along these lines are urgently needed. Aside from its possible value in destroying the apple maggot, frequent tillage of orchards in late spring and early summer is desirable, especially for young trees, as favoring a better tree and fruit development.

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[a] Seventeenth Ann. Rept. R. I. Agr. Exp. Sta., Part II, p. 191 (1904).

[b] Eighteenth Ann. Rept. R. I. Agr. Exp. Sta., Part II, p. 197 (1905).

Much infested fruit goes to market, or is stored at home for future consumption. The refuse from such fruit should always be destroyed, and the barrels and boxes in which the maggots have pupated upon leaving the fruit should be treated in such a way as to insure the destruction of the pupæ. The floor of storerooms should also be carefully swept, and the sweepings collected and burned.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *March 27, 1908.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE ASPARAGUS BEETLES.[a]

By F. H. CHITTENDEN,
*Entomologist in Charge of Breeding Experiments.*

## INTRODUCTORY.

Asparagus was introduced into this country with the early settlers from Europe, and is credited with having been cultivated here for two hundred years before being troubled with insects.

Several species of native American insects have been observed to feed upon this plant, but none, so far as we know, has become sufficiently attached to it to cause serious injury. Few of our edible plants, in short, down to the time of the civil war have enjoyed such immunity from the ravages of insects.

FIG. 1.—Spray of asparagus, with common asparagus beetle in its different stages; asparagus tip at right, showing eggs and injury. Natural size (author's illustration).

In the Old World two insects, called asparagus beetles, have been known as enemies of the asparagus since early times. In the year 1862 one of these insects, the common asparagus beetle (*Crioceris asparagi* L.) was the occasion of considerable alarm on asparagus farms in Queens County, N. Y., where it threatened to destroy this, one of the most valuable crops grown on Long Island. Subsequent

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[a] Other accounts of these insects have been published in earlier years, as follows: Yearbook U. S. Dept. Agric. f. 1896 (1897), pp. 341–352; Bul. 10, Div. Ent., U. S. Dept. Agric., pp. 54–59, 1898; Bul. 66, Pt. I, Bur. Ent., U. S. Dept. Agric., pp. 5–10, 1907.

inquiry developed the fact that the species had begun its destructive work at Astoria, near New York City, in 1860, where, it is now conceded, it was introduced about 1856.[a]

In 1881 another European importation was detected on asparagus near Baltimore, Md.—the twelve-spotted asparagus beetle (*Crioceris duodecimpunctata* L.), sometimes called the "red" asparagus beetle to distinguish it from the "blue" species.

## THE COMMON ASPARAGUS BEETLE.

(*Crioceris asparagi* L.)

From the seat of its introduction at Astoria, N. Y., the common asparagus beetle soon spread to the asparagus farms of Queens County, N. Y., and by 1862 was reported to have occasioned the loss of over a third of the crops in certain localities, the loss being estimated at $50,000.

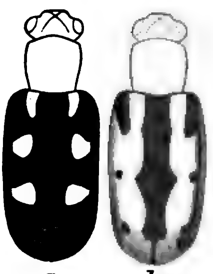

FIG. 2.—Common asparagus beetle (*Crioceris asparagi*): *a*, Dark form of beetle; *b*, light form. Enlarged (author's illustration).

Injury is due to the work of both adults and larvæ upon the tender shoots, which they render unfit for market early in the season. Later they destroy by defoliation the high-grown plants, particularly seedlings, the roots of which are weakened by having their tops devoured. The larvæ are sometimes so abundant that the black molasses-like fluid which they emit from their mouths soils the hands of those engaged in bunching the stalks for market; and the eggs are sometimes laid upon the stalks in such numbers that the latter are rendered unsightly and even slippery by their presence. Larvæ, as well as beetles, attack the tenderest portions of the plants, but the beetles gnaw with seemingly equal relish the epidermis, or rind, of the stems. The beetles are also accused of gnawing young shoots beneath the surface, causing them to become woody and crooked in growth.

In some localities it is in establishing new beds that the greatest trouble and expense are incurred. The plants must grow a year as seedlings and two more in the beds before being cut for table use, and during these three years they are constantly exposed to the attacks of this insect.

The beetle is a beautiful creature, slender and graceful in form, blue-black in color, with red thorax, and with lemon-yellow and

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[a] The capture of this species was recorded early in the past century in Pennsylvania—presumably near Hanover—and again in the vicinity of Chicago and Rock Island, Ill., about ten years after the discovery on Long Island; but, as the insect did not obtain a permanent foothold, but died out in these localities, these importations can not be considered introductions.

dark-blue wing covers having a reddish border. A common form about the District of Columbia is illustrated in fig. 3, *a*. Farther north the prevailing form is darker, the lighter coloring sometimes showing only as a reddish border and six small submarginal yellow spots (fig. 2, *a*). An extreme, light form not uncommon in the southern range of the insect is shown (fig. 2, *b*) for comparison. The length is a trifle less than one-fourth inch.

### HISTORY OF SPREAD.

From the scene of its first colonization in Queens County, the insect migrated to the other truck-growing portions of Long Island. It soon reached southern Connecticut, and has now extended its range northward through that State and Massachusetts to the State line of New Hampshire. Southward it has traveled through New Jersey, where it was first noticed in 1868, eastern Pennsylvania, Delaware, and Maryland to southern Virginia and North Carolina.

Its distribution by natural means has been mainly by the flight of the beetles. Undoubtedly, also, the beetles have been transported from place to place by water, both up and down stream by rising and falling tide, as the fact that it has not until recently deviated far from the immediate neighborhood of the seacoast and of large water courses near the coast bears abundant testimony.

Another reason for the prevalence of this species in these localities is that asparagus was originally a maritime plant and has escaped from cultivation and grown most luxuriantly in the vicinity of bodies of water. It is well known that it is usually upon wild plants that these insects first make their appearance in new localities. There is evidence also that their dissemination may be effected by what Doctor Howard has termed a "commercial jump," either by commerce in propagating roots, among which the insects may be present either as hibernating beetles or as pupæ, or by the accidental carriage of the beetles on railroad trains or boats.

By some such artificial means the asparagus beetle had found its way to northwestern New York, between Rome and Buffalo, and to Ohio, between Cleveland and the Pennsylvania State line. During 1896 its course was traced along the Hudson River above Albany. Inquiry concerning the Ohio occurrence disclosed the fact that the plants in one locality were brought from New York. The presence of this insect in eastern Massachusetts at about the same time was in like manner probably due to direct shipments of roots from infested localities to Boston and vicinity.

It is noticeable that up to this time its inland spread, except in the neighborhood of water, had been extremely limited.

## DISTRIBUTION IN 1908.

This species is present now in what is known as the Upper Austral life zone, although in certain points in New England it has located in what is considered the Transition zone. Its course up the Hudson River lies within a rather narrow strip of Upper Austral. In all probability it is destined in time to overspread the entire Upper Austral zone and to make its way to some extent into neighboring areas in which it may find conditions for its continuance.

Its distribution in Massachusetts, though wide, is local. In New Hampshire it has been recorded from Nashua and Portsmouth. It is possible that in a few years it may be able to encroach slightly upon the bordering States of Vermont, in the vicinity of the Connecticut River Valley, and Maine, near the New Hampshire seaboard. It is well established in Connecticut, occurs in Rhode Island, and is generally distributed through New Jersey, Delaware, and Maryland. and in southeastern Pennsylvania near the Delaware River. It was predicted by the writer that, although this species in 1896 was still local in New York and Ohio, we might expect within a few years to hear of its invading other portions of those States lying within the Upper Austral zone; Canada, of which there is a strip of Upper Austral bordering the northern shore of Lake Erie; and, later, Indiana, Illinois, Kentucky, and States farther west. By 1897 the species had occupied the strip bordering the southern shore of Lake Erie, being recorded from nine counties of eastern Ohio. The following year it was noticed in western Virginia. In 1898 it was reported from Benton Harbor, Mich., where, however, it had been present since 1896. By 1899 it had appeared in Canada in the Niagara River region and was accompanied by the twelve-spotted species. The insect obviously received more or less severe setbacks in succeeding years, but by 1904 the common form was observed about Toronto, Canada, and about 4 miles west of Chicago, Ill. It has now become very generally distributed in the asparagus-growing sections of New York State, having reached Glens Falls, its northernmost recorded limit in the United States. In Ohio the species has been established near Columbus since 1903, and near Cincinnati since 1905, but has not been reported from Kentucky or Indiana, although it has probably invaded the latter State.

In 1904 the occurrence of this insect at Bouldin Island, California, was reported, but the following year it could not be found. Its disappearance was attributed to the fact that the island had been flooded, causing the death of the pest. In 1906, however, the beetle was reported in abundance near Oakley, Cal.

In North Carolina the species is well established in the east-central part, including portions of Wake, Wayne, Warsaw, and Duplin coun-

ties. The species has also been reported in Wisconsin, but nothing has been learned regarding its actual distribution in that State.

### HABITS AND LIFE HISTORY.

The common asparagus beetle passes the winter in the adult state under convenient shelter, such as piles of rubbish, sticks, or stones, or under the loose bark of trees and fence posts. Toward the end of April or in May, according to locality, at about the season for cutting the asparagus for market, the beetles issue from their hibernating quarters and lay the eggs for the first brood.

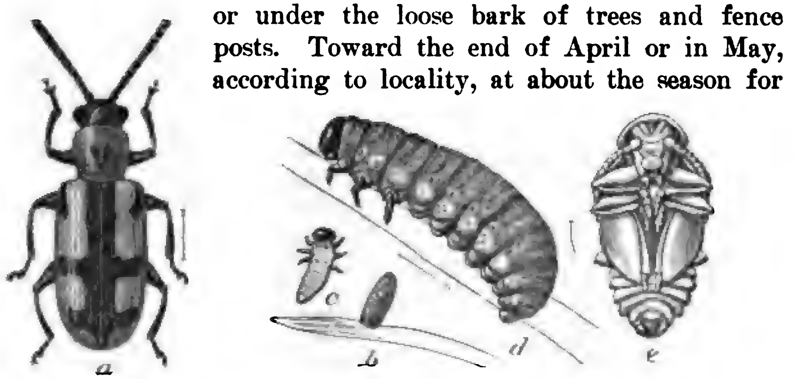


Fig. 3.—Common asparagus beetle (*Crioceris asparagi*): *a*, Beetle; *b*, egg; *c*, newly hatched larva; *d*, full-grown larva; *e*, pupa. All enlarged (author's illustration).

The egg is very large in proportion to the beetle, being nearly a sixteenth of an inch in length, and of the elongate-oval form illustrated at *b* (fig. 3). It is nearly three times as long as wide and of a dark-brown color. The eggs are deposited endwise upon the stem or foliage and in early spring on the developing stalks, usually in rows of 2 to 7 or more (fig. 4).

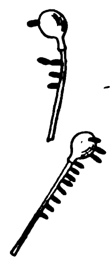

Fig. 4.—Eggs of common asparagus beetle (*Crioceris asparagi*) on asparagus buds. Somewhat enlarged (original).

In from three to eight days the eggs hatch, the young larvæ, commonly called "grubs" or "worms," presenting the appearance indicated in fig. 3, *c*. The head of the newly hatched larva is large, black, and bead-like; its body is gray; and its three pairs of legs, black. It at once begins to feed, and is from ten days to a fortnight, according to Fitch and others, in attaining full size. When full grown the larva appears as in fig. 3, *d*. It is soft and fleshy, much wrinkled, and of a dark gray or olive color, sometimes light, but not infrequently very dark. The head is shining black, as are also the six legs. Each segment is provided with a pair of foot-like tubercles, which, with the anal proleg, assist it in crawling and in clinging to the plant. The mature larva enters the earth, and here, within a little rounded, dirt-covered cocoon which it forms, the pupa state is

assumed. The pupa is yellowish in color, and its appearance is sufficiently shown by the illustration (fig. 3, *e*). In five to eight or more days the adult beetle is produced, which in due time issues from the ground.

### THE LIFE CYCLE.

Of the duration of the life cycle Fitch has remarked that it is about thirty days from the time the egg is laid until the insect grows to maturity and comes out in its perfect form, but that the time will be shorter in the hottest part of the season than in the cooler days of May and June. These periods are for Long Island.

During a hot spell in midsummer the minimum period of ovulation and of the pupa stage was observed at Washington, D. C. Eggs that were laid on the 5th of August hatched on the 8th, or in three days. A larva transformed to pupa on August 4 and to adult August 9, or in five days. Allowing ten days as the minimum credited period of the larval stage, a day or two for the larva to enter the ground and form its cocoon, and two or three days more for the beetle to mature and leave the earth, the insect is again ready to attack its food plant and to continue the reproduction of its kind in about three weeks from the time that the egg is laid.

This may be fairly taken to represent the minimum midsummer life-cycle period of the species in the District of Columbia and southward. In the colder climate of New England, and elsewhere in spring and autumn weather, the development from egg to beetle will require from four to perhaps seven weeks. The hibernating beetles appear in the latitude of the District of Columbia as early as April, and beetles of a later brood have been observed in abundance in October as far north as northern Connecticut. In its northern range two and perhaps three broods are usually produced, and farther south there is a possibility of four or five generations each year.

### NATURAL CHECKS.

The common asparagus beetle has very efficient natural checks in the shape of predaceous insects of many kinds, which prey upon its larvæ and assist very materially in preventing its increase. One of the most efficient of these is the spotted ladybird, *Megilla maculata* DeG. The beetle is rose-colored, with numerous black spots. The convergent ladybird (*Hippodamia convergens* Guer.), the spined soldier-bug (*Podisus maculiventris* Say), and the bordered soldier-bug (*Stiretrus anchorago* Fab., fig. 5) are also active destroyers of asparagus beetle larvæ, which they attack and kill by impaling them upon their long proboscides and sucking out their juices. Certain species of wasps and small dragon-flies also prey upon the asparagus beetle grubs. Two of the most abundant of

these are *Polistes pallipes* Lep. and *Ischnura* (*Nehalennia*) *posita* Hagen. These insects hover about the infested plants until a larva is descried, when they pounce upon it and carry it away.

Asparagus beetles are very susceptible to sudden changes of temperature, and it has been frequently noticed by Mr. C. W. Prescott, of Concord, Mass., that immense numbers of the hibernating beetles are killed in winter during severely cold spells following " open " weather, millions of their dead bodies being sometimes found under bark and in other hiding places.

The intense heat that prevailed at times during the summer of 1896, especially during the first two weeks of August, though conducive to the undue propagation of some forms of insects, had the opposite effect upon certain species that feed in the larval condition freely exposed upon the plants. In the vicinity of the District of Columbia this was particularly noticeable in the case of the larvæ of this aspara-

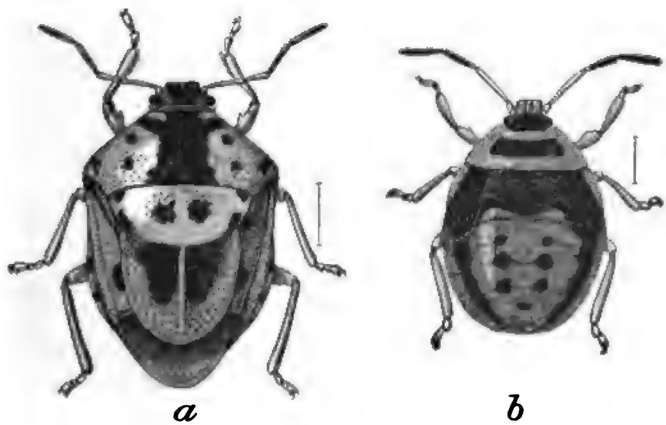

FIG. 5.—Bordered soldier-bug (*Stiretrus anchorago*): *a*, Adult bug; *b*, last stage of nymph. Both enlarged (author's illustration).

gus beetle. Its eggs also seemed to be dried up by the heat. What with the decimation caused by their natural enemies and the heat, scarcely a beetle or larva was to be found that year after the last of August.

### REMEDIES.

Fortunately, the common asparagus beetle is not difficult of control, and ordinarily may be held in restraint by the simplest means.

*Hand-picking* is of value in small beds but must of necessity give way to more approved methods for the vast numbers of the beetles that concentrate their forces upon the large areas devoted to this crop in the suburbs of our large cities.

*Chickens and ducks* are efficient destroyers of asparagus beetles, and as they do no injury to the plant their services are still in requisition for this purpose at the present day.

*Cultural practices.*—A practice in high favor among prominent asparagus growers is to cut down all plants, including seedlings and volunteer growth, in early spring, so as to force the parent beetles to deposit their eggs upon new shoots, which are then cut every few days before the eggs have time to hatch for the first new brood.

Other measures that have been employed with advantage consist in cutting down the seed stems after the crop has been harvested, and again once or twice during the cutting season, or in permitting a portion of the shoots to grow and serve as lures for the beetles. Here these may be killed with insecticides, or the plants, after they become covered with eggs, may be cut down and burned, and other shoots allowed to grow up as decoys. The trap plants should be destroyed as often as once a week.

With concerted action on the part of growers in following out any of these last methods the insects may be held in check, at least in a region where asparagus does not grow wild in too great profusion. Where this is not practicable, insecticides must be brought into service. It is well in any case to employ insecticides after the cutting season, since if the insects are destroyed at this time their numbers will be lessened for the next year.

*Lime.*—One of the best remedies against the larvæ is fresh, air-slaked lime, dusted on the plants in the early morning while the dew is on. It quickly destroys all the grubs with which it comes in contact.

*Pyrethrum* is credited with being useful, and a mixture of soft soap, quassia decoction, and water (about equal parts of the first two to 5 of the last named) is effective against the larvæ; but these remedies hardly commend themselves for extensive use.

*Arsenicals.*—The arsenicals, applied dry mixed with flour, as for potato beetles, answer well; they possess the advantage of destroying beetles as well as grubs, and are of value upon plants that are not being cut for food. Some use a mixture of Paris green and air-slaked lime, or plaster, 2 pounds of the former to a barrel of the latter. To produce satisfactory results the lime or arsenical must be applied at frequent intervals, or as often as the larvæ reappear on the beds.

Arsenate of lead has given excellent results. This insecticide has come into very general use in recent years for the control of leaf-feeding beetles, such as the potato beetles and asparagus beetles. In Connecticut Dr. W. E. Britton tested it on asparagus, spraying the plants from all four sides in succession because of the slight leaf exposure as compared with most other forms of plants. Good results followed. The same amount of benefit should be accomplished with scarcely greater expense by spraying from opposite sides and repeating this

before the beetles of the last generation develop or at least in time to destroy them before they get into winter quarters. In Pennsylvania Prof. H. A. Surface made a comparative test of the value of Paris green and arsenate of lead, learning that not more than 50 per cent of the insects were killed when Paris green and lime were used, while 90 per cent were killed with arsenate of lead. In a third experiment, in which resin soap was added to make the latter insecticide adhere more closely to the plants, all of the insects were killed on 50 plants treated. In this case the arsenate of lead was used at the rate of 1 pound to 24 gallons of water, and 2½ pounds of resin soap was added to render the mixture more adhesive.

In the North, where these experiments were made, they were begun the first of June. Arsenate of lead has been used with satisfactory results on asparagus at the rate of 1 pound in 16 gallons of water, but some additional experiments are necessary to ascertain the exact amount of the poison that can be used economically to produce the required result. In ordinary weather a second spraying of arsenate of lead with a resin soap added is desirable, especially if rainfall intervenes.

More specific information in regard to the method of preparing and applying arsenate of lead is given in Circular No. 87, which may be obtained gratis on application.

Everything considered, injury by this species is most noticeable when the beetles are working on the asparagus tips at the time they are being cut for food or market, as more fully described on page 2. It is, of course, impossible to apply arsenicals to the edible product owing to the danger of poisoning human beings. About all that can be done at this time is to cut as frequently as possible, but after the cutting season is over the arsenicals may be freely used in accordance with the directions already given.

*The brushing method.*—A simple and inexpensive method of killing the larvæ in hot weather is to beat or brush them from the plants with a stick so that they will drop to the bare ground. The larvæ are delicate creatures, and, as they crawl very slowly, few are able to regain shelter of the plants, but die when exposed to the heated earth. The same method is in use against the pea aphis.

## THE TWELVE-SPOTTED ASPARAGUS BEETLE.

(*Crioceris duodecimpunctata* L.)

A rarer, and consequently less injurious species than the preceding is the twelve-spotted asparagus beetle. It is generally distributed in Europe, where it is apparently native and, although common, not especially destructive. Like the preceding, it lives exclusively on asparagus, and the chief damage it does is due to the

depredations of the hibernated beetles in early spring upon the young and edible asparagus shoots. Later generations attack the foliage, living, for at least a considerable portion of the larval stage, within the ripening berries.

### INTRODUCTION AND SPREAD IN THE UNITED STATES.

The presence of this insect in America, as has been stated, was first discovered in 1881, and in the vicinity of Baltimore, Md. This beetle was noticed in considerable numbers from the first, showing that it had probably been introduced several years earlier. At that time it was quite local, occurring only at the mouth of the Furnace Branch of the Patapsco River at a point a few miles south of Baltimore. It was then seen only on volunteer asparagus growing on the salty margin of this river, although beds of cultivated asparagus were plentiful in the immediate vicinity. Two years later it had proved even more troublesome than the common asparagus beetle.

Assuming Baltimore to have been the original center of distribution, the twelve-spotted asparagus beetle has been traced southward through Anne Arundel and Prince George counties to the District of Columbia, where it was detected five years from the time of its first discovery.

In 1892 it was reported to have appeared in considerable numbers on asparagus stalks that had been cut down upon a farm in Carroll County, Md. The same year its appearance was announced in Gloucester County, in southern New Jersey, and the following year in Cumberland and Camden counties of the same State. To have reached these points the insect, obviously, had traversed the intervening territory in Maryland, the northern half of Delaware, and Salem County, N. J. It was also found to have reached Virginia, near Washington. In 1894 it had extended northward to Burlington County, N. J., and westward to Philadelphia County, in Pennsylvania. The same year it was detected in Queen Anne County, Md., and near Rochester, N. Y. Two years later it established itself in Charles County, Md., and had penetrated as far south in Virginia as Westmoreland County.

In May, 1896, a serious invasion was reported in Prince George County, Md., where the beetles attacked the young shoots, gnawing off the heads as soon as they showed above ground, thus entirely unfitting the crop for market.

Nearly every year since, it has been reported in new localities in the United States and Canada until now it is well distributed westward and northward. In 1898 it had become generally distributed in New Jersey "south of the shale from the Atlantic coast to the Delaware." Next year it was recorded in twelve counties in New York as far west

as Buffalo and in the following years generally throughout New York State, as also in the Niagara district in Canada.

An interesting fact in the occurrence of the asparagus beetles in the Niagara peninsula was that the two species arrived almost simultaneously and that the twelve-spotted form was the dominant one. By 1902 the latter had appeared in Connecticut, at New Haven, and later in other portions of that State.

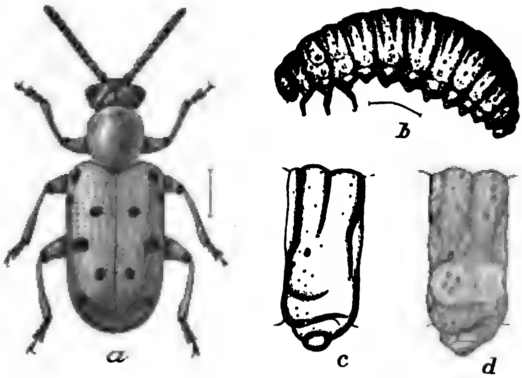


FIG. 6.—Twelve-spotted asparagus beetle (*Crioceris duodecimpunctata*): *a*, Beetle; *b*, larva; *c*, second abdominal segment of larva; *d*, same of *C. asparagi*. *a*, *b*, Enlarged; *c*, *d*, more enlarged. (Author's illustration.)

### DESCRIPTION, LIFE HISTORY, AND HABITS.

The mature beetle rivals the common species in beauty, but may be distinguished by its much broader elytra and orange-red color. Each wing cover is marked with six black dots, and the knees and a portion of the under surface of the thorax are also marked with black (fig. 6, *a*). The beetle, as it occurs on the plant when in fruit, very closely resembles at a little distance the ripening asparagus berry.

The common asparagus beetle, as is well known, dodges around a stem like a squirrel when disturbed, but the twelve-spotted form appears to trust to flight, taking wing more readily. Both species make a loud creaking sound when handled, by what is called stridulation, produced in the present species by rubbing the tip of the abdomen against the elytra.

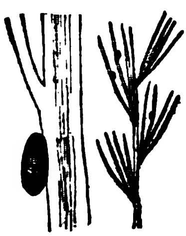

FIG. 7.—*Crioceris duodecimpunctata*: Egg, natural size, on asparagus leaves at right; same, enlarged, at left. (Author's illustration.)

The full-grown larva is shown at *b* (fig. 6). It measures, when extended, three-tenths of an inch (8 mm.), being of about the same proportions as the larva of the common species, but is readily separable by its orange color. The ground color is light yellowish cream with an overlay of ochraceous orange which is most pronounced on the exterior portions of the abdominal segments. The head, with the exception of the mouth-parts, is also ochraceous, the thoracic plate is prominent, divided into two parts, and is of a dark-brown color. Enlarged figures of the second abdominal segment of both species are presented at *c* and *d* (fig. 6) for comparison.

In Europe, where this species is native, it is common, but not especially destructive.

The chief damage is from the work of the hibernated beetles in early spring upon the young and edible asparagus shoots. Later beetles as well as larvæ appear to feed exclusively on the berries. The eggs are deposited singly, and apparently by preference, upon old plants, toward the ends of shoots, which, lower down, bear ripening berries, and they are attached along their sides (fig. 7), instead of at one end as with the common species. Soon after the larva hatches it finds its way to an asparagus berry, enters it, and feeds upon the pulp. In due time it leaves this first berry for another one, and when full growth is attained it deserts its last larval habitation and enters the earth, where it transforms to pupa and afterwards to the beetle. The life cycle does not differ materially from that of the common species, and there is probably the same number of generations developed, or nearly as many.

## REMEDIES.

The remedies are those indicated for the common asparagus beetle, with the possible exception of caustic lime and some other measures that are directed solely against the larvæ of that species, but the habit of the larva of living within the berry places it for that period beyond the reach of insecticides. The collection and destruction of the asparagus berries before ripening might be a solution of the problem, but it is questionable if recourse to this measure would be necessary, save in case of an exceptional abundance of the insect.

Approved:
James Wilson,
*Secretary of Agriculture.*

Washington, D. C., *April 15, 1908.*



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CIRCULAR No. 103. Issued June 20, 1908.

United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE HARLEQUIN CABBAGE BUG.

(*Murgantia histrionica* Hahn.)

By F. H. CHITTENDEN,

*Entomologist in Charge of Breeding Experiments.*

## INTRODUCTORY.

A moderate-sized red and black plant-bug, variously known as "calico back," "fire bug," and "terrapin bug," as well as harlequin

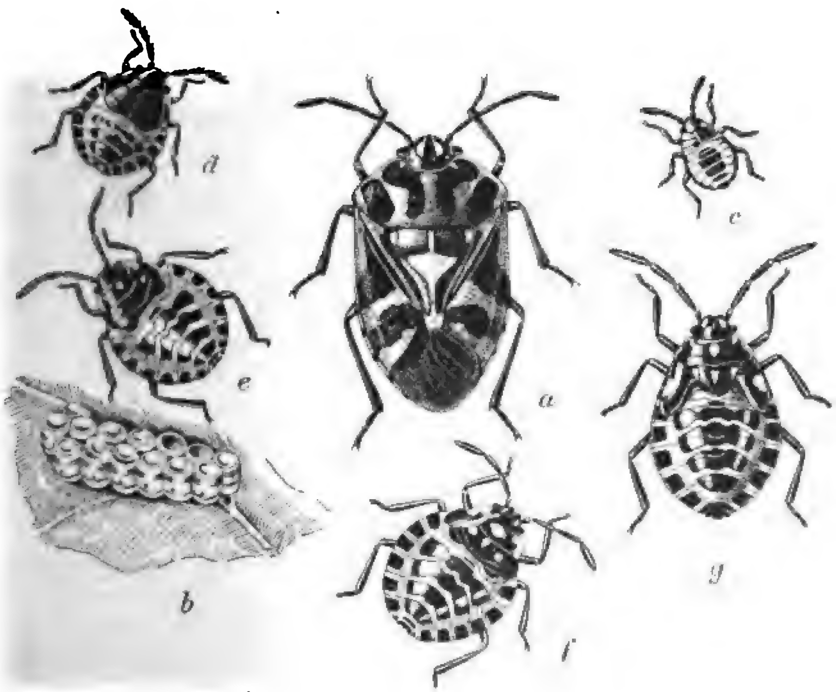

FIG. 1.—Harlequin cabbage bug (*Murgantia histrionica*): *a*, Adult; *b*, egg mass; *c*, first stage of nymph; *d*, second stage; *e*, third stage; *f*, fourth stage; *g*, fifth stage. All enlarged (original).

cabbage bug, is the most destructive insect enemy of cabbage and related crops in the southern part of the United States. At one time it was a serious pest northward to New Jersey and westward to Ohio

and, indeed, threatened to invade New York and New England. In recent years, however, its progress in the northern States has been checked by atmospheric conditions.

This plant-bug accomplishes its work of destruction by sucking the sap from leaves and veins of cabbage and other crucifers, the affected plants wilting, withering, and dying as if they had been swept by fire, whence the name "fire bug." It is a pest which, if permitted to propagate unmolested in seasons which favor its increase, is certain to destroy a portion if not all of the fields which it infests. A half dozen mature insects are capable of destroying a small plant in one or two days. Some years ago, when this species was abundant in the vicinity of the District of Columbia, the writer saw many large fields in Maryland and Virginia from which not a single good cabbage could be picked, and observed similar injury to horse-radish and some other crucifers.

The harlequin bug has been compared to the boll weevil as a pest in the South and to the San Jose scale as a scourge in New Jersey. Certainly it is to the cabbage grower what the other two insects are to the cotton planter and fruit raiser respectively. If growers generally, however, will undertake the methods of control, as advised in this circular, there is no reason why it should be longer destructive.

## DESCRIPTIVE.

The name harlequin cabbage bug scarcely requires explanation to any one familar with the appearance of the insect. Its gay red and black ornamentation is suggestive of the dress of the stage harlequin. In the figure of the adult (fig. 1, *a*) the dark portions illustrated are either black or dark metallic blue and the light portions are bright yellow in freshly transformed bugs and red in fully hardened individuals.

The eggs (fig. 1, *b*) are beautiful objects and remarkable for the fact that they closely imitate in miniature white barrels bound with black hoops and with black spots set in the proper place for bungholes.

The younger stages, or nymphs, of this species bear considerable resemblance to the mature form, differing, however, in the lack of wings and in having only four joints to the antennæ, whereas the adult has five. There are five stages in all, illustrated at *c*, *d*, *e*, *f*, and *g*. In the third and fourth nymphal stages the body is hemispherical and the resemblance to a turtle or terrapin is striking.

## DISTRIBUTION.

The harlequin cabbage bug is a native of Mexico and Central America—where it obviously originated—and perhaps also of the semitropical regions in Texas, Arizona, and New Mexico. It was first

recorded in injurious numbers in Texas, in Washington County, in 1864,[a] and since then has traveled gradually northward, although not with uniform rapidity. Normally the species is probably tropical and has been diffused through two additional life zones, the Lower and Upper Austral. In the latter zone, however, it has not become permanently established much farther north than about the lower or warmer half. The region about Norfolk, Va., "the gateway of the South," is probably the northern limit of actual establishment in the East.

A year or two following its discovery as a pest this species had invaded Louisiana, and by 1867 was recorded from North Carolina. Its spread was most noticeable along the Atlantic seaboard and up the Mississippi River valley. In 1870 it had appeared in Missouri and Tennessee, and by 1876 had reached Delaware. In Maryland and Virginia, however, it did not attract attention until 1880. It was first recorded as injurious in New Jersey, at Woodbury, in 1892,[b] and in 1894 it was seen at Jamaica and "New Lots Road," New York.[c]

Westward we have office records of its occurrence in Colorado in 1882, at Pueblo and Denver, but it has never been an important pest in that region, and it was not until 1890 that it was recorded in Indiana and not till 1891 in Ohio. In the latter State it progressed steadily northward until it was checked by the same atmospheric conditions which prevailed in the Eastern States and which will be mentioned presently. In the Pacific region the species is well established in southern California, but there seems to be no published record of the time of its first appearance in that State. We received specimens from San Diego, Cal., as early as 1878. The insect is also recorded from Nevada.

The dispersion of this species in the Middle States has been traced by Mr. F. M. Webster,[d] and from what has just been stated and what has been placed on record by Messrs. Webster and Howard it is very evident that it has become diffused largely by what Doctor Howard terms "commercial jumps," as in the case of insects like the asparagus beetle. This is a matter quite simple of accomplishment, as fertile egg masses can be carried long distances on the insect's food plants—for example, on the outer leaves of cabbages—by railroads and by boat. It will be noted that after the establishment of the pest in Delaware it did not attract attention farther north until twenty years later; also, that other introductions were made in different directions quite independently of each other.

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[a] Recorded by Gideon Lincecum, Practical Entomologist, Vol. I, p. 110, Aug. 21, 1866.

[b] Lintner, 9th Rept. New York State Ent. f. 1892 (1893), pp. 315–317, 441.

[c] Sirrine, Bul. 83, New York Agl. Exp. Sta. (Geneva), Dec., 1894, p. 683.

[d] Proc. Ent. Soc. Wash., Vol. III, pp. 288–290, 1896.

To recapitulate: This species has obviously become diffused from a central point of dispersal, Mexico, chiefly in the following three directions: (1) From Texas eastward through the Gulf States and northward along the Atlantic seaboard to Long Island; (2) from Texas northward through the Mississippi Valley and thence through the Ohio River region into Ohio; (3) from Mexico into the neighboring States and Territories, and from Lower California into southern California and Nevada.

The northward migration of the harlequin bug, although not without interruption, was apparently quite steady until recent years. Beginning with the year 1897, at which time the insect had reached its maximum as a pest in Maryland, Virginia, Delaware, and adjoining States, climatic conditions adverse to its existence developed. These consisted of sudden changes of temperature, such as cold snaps followed by warm spells and the reverse during the winter. As a result this bug, with several other forms of southern origin, was killed while hibernating and practically disappeared in the North until, at the date of writing (1908), it is scarcely, if ever, reported as injurious from the District of Columbia northward. These conditions were particularly noticeable in the winter of 1898–99.[a] Small scattering colonies are, however, occasionally found in this region, chiefly on wild plants, late in the fall.

## LIFE HISTORY.

In the warm and equable climate of the South where this species is at home it is more or less active throughout the year. Farther northward, however, after the first severe frosts of December it goes into hibernation in tufts of grass or under rubbish at the bases of cabbage stalks or in any convenient place. This takes place chiefly in the adult stage, although some nymphs of the last stages remain afield as late as November and December. Doubtless the nymphs succumb in time to cold, and hence fail to survive the winter.[b] The first warm days of February or March, in the Gulf region, or of April, farther north, see the bugs appear abroad and beginning to feed. At first wild mustard and other cruciferous weeds are attacked and soon the insects are ready to reproduce their kind. On these wild plants the eggs are deposited, on end, generally in two more or less

[a] See Bul. 22, n. s., Div. Ent., U. S. Dept. Agric., pp. 54, 55.

[b] A number of adults and nymphs in the last two stages obtained from Lambert's Point, Va., October 21, 1907, were placed in a rearing cage with growing cabbage plants, grass, and similar rubbish to provide means of hibernation. For over a month or until some time in December the insects continued feeding, but when examined during the first week of March it was found that all had succumbed to the severe cold weather of February.

parallel rows cemented together in groups of about a dozen, as shown in figure 1. They are normally placed on the under side of the leaves and hatch, in warm weather, in three or four days after deposition and in five to eight days in the cooler weather of early spring. The young bugs or nymphs pass through their five stages of metamorphosis with considerable rapidity. It has been stated that the life cycle could be completed in warm weather in about two weeks, but this is obviously an exaggeration, as it requires four or five weeks for the completion of the cycle in related insects.

The life periods of this species were unknown until worked out by Mr. H. O. Marsh, of this office. Specimens (from Texas) were under observation from the first week of March until the first week of May. They were under somewhat unnatural conditions, being confined in our office room, which was maintained during this period at an average temperature of from 68° to 70° F. The first or egg stage covered 11 days. The time from the hatching of the eggs until the first molt gave the first larval instar or nymph period 7 days; the second instar required 13 days; the third, 8 days; the fourth, 14 days, while the fifth or pupal instar covered 17 days—a total of 70 days, or 10 weeks, in all, which will be not far from the maximum active period of this species. The minimum will probably fall into much lower figures, probably half of this time, or at most not more than 42 days in extremely hot midsummer weather.

When cabbage and similar plants come up the insects migrate to them. It has been surmised that owing to the rapid development of the cabbage bug in the South there is a possibility of as many as seven or eight generations each year, while in the North three or more occur. The first supposition is doubtless overdrawn, as we know of no similar insect producing so many generations annually. This is a problem for future study. It seems probable that four or five generations would be a more natural limit in the South and two, or possibly three, in the North.

## FOOD PLANTS.

In the autumn after the cabbage crop has been made and in early winter, even as far north as Washington, the bugs are still afield, seeming loath to seek shelter for the cold months. At this time they cluster on cabbage stalks and sprouts and the leaves of turnip and like plants, and when the supply of crucifers has become exhausted they will attack almost any form of succulent vegetation which is most available and palatable.

On one farm the writer observed a field of 10,000 cabbage plants completely ruined, which at the time of his visit, the first week in October, had been deserted by the bugs. An adjoining field of pota-

toes was then attacked, afterwards one of eggplant, and numerous bugs in various stages were observed sucking the juices of these plants. Unripe fruit of eggplant was especially relished, and ripe pods of okra and beans were also attacked.

The list of useful plants which this species has been found to damage includes all forms of crucifers or cole crops—cabbage and related plants, kale, collards and cauliflower, turnips, radish, horse-radish, mustard, rape, and the like—and when these crops have been killed out truck crops of nearly all kinds are attacked, of which eggplant, asparagus, potatoes, tomatoes, okra, beans, and beets are most affected. Damage is sometimes done to ornamental plants such as roses, sunflowers, and chrysanthemums in flower gardens, and Mr. J. M. Rankin, while an agent of this Bureau at Chico, Cal., in October, 1905, reported that this species, after entirely destroying a half-acre plat of cabbage, attacked the other plants in the vicinity, including nursery plants of citrus, loquat, cherry and plum, squash, eggplant, "and in fact everything green." The fruit of grapes and late corn has also been attacked. The bugs are very partial to ragweed (Ambrosia), pigweed (Amarantus), wild lettuce (*Lactuca canadensis*), and lambsquarter (Chenopodium), congregating on all parts of these weeds but appearing to prefer the stems.

The wild food plants on which the species actually breeds include wild mustard and cresses of different kinds, shepherd's purse, pepper-grass, bitter-cress, rock-cress, and practically all other plants of the mustard family (Cruciferæ) as well as some of the closely related caper family (Capparidaceæ).

## NATURAL ENEMIES.

The comparative freedom from the attack of natural enemies which the harlequin cabbage bug enjoys is remarkable, and is due to two causes: First, to the warning type of its coloration—black and red or yellow; and, second, to its distasteful odor and flavor. This latter has been tested frequently. In the writer's experience birds that would attack most common insects would, when offered one of these bugs, either peck at it or look at it askance, or if by chance they ate a bug they did not repeat the dose.

Nevertheless the insect has one effective natural enemy, a minute parasite, *Trissolcus murgantiæ* Ashm., which develops in the egg. Prof. H. A. Morgan when in Louisiana discovered that out of over a thousand eggs under observation in 1902 nearly all were killed by this useful little creature. The eggs are also attacked by *Ooencyrtus johnsoni* How. and have been parasitized artificially by *Trissolcus podisi* Ashm.

This species is also preyed upon by another bug, *Arilus cristatus* L., the wheel bug, which the writer has frequently seen attacking the young harlequins.

The influence of natural elements, particularly cold winters, has already been mentioned as a means of decimating this pest. It is well to add, however, that the writer had this species under close observation in 1899, and that as a result of sudden cold snaps, 85 per cent of the bugs in fields near Washington in that year had been killed by January 15, 1900.

### METHODS OF CONTROL.

The experience of years has shown that in order to obtain the best results in the treatment of the harlequin cabbage bug preventives are necessary, as there is great difficulty in obtaining insecticides which are effective and which do not at the same time injure or kill the plants. These preventives are: (1) Clean cultural methods, especially in the fall; (2) the use of trap crops of mustard or other plants in the spring, and (3) hand methods. With strict observance of clean farming few of the insects will survive the following spring and the adoption of trap crops leaves fewer still to be destroyed by mechanical measures. In some cases all three methods should be adopted, for if they are neglected the grower will find it a most vexatious matter to control the pest in the midst of the growing season.

*Clean cultural methods.*—Of prime importance are clean cultural methods. The value of clean methods of farming has been recognized by nearly everyone who has had experience with this insect. The practice of leaving stalks of cabbage and other cruciferous plants in the field late in the autumn and in the early winter. or of permitting rank weeds to grow up, or, in fact, allowing any sort of débris to accumulate, serves as a means of protracting the life of this insect, as all such material either affords it food late in the season or quarters for protection against the elements during winter. It is even inadvisable to plant crucifers in the vicinity of outhouses and barns, as the bugs are apt to enter these latter for passing the winter.

Throughout the year wild plants of the mustard family, on which the insect chiefly breeds, should be carefully kept down not only in the fields but in the immediate neighborhood. A list of such plants is given on page 6.

*Trap crops.*—Some plants, such as cabbage, turnip, or kale, may be planted late, to be left at intervals throughout infested fields. These trap plants attract the insects in the fall, and here the latter may be killed with pure kerosene, or by mechanical methods. Where it is convenient to leave piles of rubbish until the insects are attracted to them this may be done, and the entire material, insects and all, should then be burned.

The best remedy, however, and one that should be put into operation by every cabbage grower who is troubled by this pest, consists in planting an early crop, which may be either mustard, rape, or kale, as a lure for the first-appearing insects. Radish and turnip serve a similar purpose. In the Gulf States the overwintered adults appear in February and March, and in the District of Columbia and vicinity in the latter part of April. For some reason they appear to prefer the plants that have been enumerated, and wild mustard and other crucifers, for the first deposition of their eggs. On these crops and on weeds the insects can be killed with kerosene or by the hand torch or may be collected in nets, or they may be destroyed by burning the entire trap crop when this is of no special value. Numerous reports have been received at the Department of Agriculture, and others have been recorded, of the value of trap crops as a means of controlling this pest. Some of these are worth repeating.

The first test of the trap-crop remedy was made by Lincecum (l. c.) in Texas, in 1866. Noticing that the bugs were numerous on mustard and radish in April, he handpicked them and thus protected his cabbage crop. The practical utility of this method, however, does not appear to have been recognized until considerably later. In 1891, Mr. H. E. Weed, when entomologist of the Mississippi Agricultural Experiment Station, sowed a row of mustard through the center of a 1-acre field of cabbage. In April this mustard attracted the bugs in large numbers and on it they were killed with undiluted kerosene, with the result that throughout that season the field remained free from the pest, whereas the previous year the crop was almost entirely destroyed.[a]

*Hand methods.*—If determined efforts are made to stamp out the first generation fewer insects will remain to be dealt with and very

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[a] A correspondent, Mr. J. H. Hevey, Ingomar, Miss., tested the trap-crop remedy, and wrote that when the bugs made their appearance on a bed of mustard he destroyed them by "bugging," i. e., by shaking them into pans of water on which a thin film of kerosene was floating. When the mustard was removed to make room for another crop a few cabbage plants became infested, but the bugs were killed as above, and finally, after the middle of July, none was left.

One of the largest growers of cabbage in Delaware reported (Sanderson, Bul. 26, n. s., Bur. Ent., U. S. Dept. Agric., p. 67, 1900) that at one time it was impossible to raise cabbage on account of this pest, but for several years he had used kale as a trap crop, and as a result of this procedure and careful handpicking of the few bugs that strayed to the cabbage, he had been troubled very little, while his neighbors' cabbage had frequently been ruined.

In April of one year in Maryland half an acre of kale became freely infested on one side by harlequin bugs. The insects had all congregated on this side. Under the writer's direction this portion was burned, straw being used to facilitate ignition. Two weeks later not a single bug could be found in a walk about this patch, and the cabbage which was growing in several plats in the vicinity was free from injury.

few will fly from other quarters for the continuation of the species. Thus injury may be greatly curtailed if not absolutely prevented for an entire season. The large size and bright colors of the insect render it easy of detection and its sluggish nature assists in its easy capture. Mr. H. Walter McWilliams, Griffin, Ga., reports that by offering a bounty to school children for the destruction of this pest he succeeded, in March and April, 1902, in destroying the first generation in that vicinity, and estimated that this experiment saved him $100 on his cabbage crop alone, not counting the benefit to the children.

As instance of the ease with which this insect may be hand-picked, a grower at Denton, Tex., gathered, in February of one year, 47,000 bugs. In case hand-picking has not been thoroughly done and some bugs have escaped this process and succeeded in depositing their eggs, the masses, which may be easily recognized by comparison with figure 1, *b*, should be carefully gathered and crushed.

*Kerosene emulsion*, according to the testimony of many who have experimented with it, is not effective against the adults and only partially effective when sprayed on the younger nymphs. Quite recently Prof. A. F. Conradi [a] has found that a 10-per-cent kerosene emulsion is effective in killing the nymphs, as is also whale-oil soap, at the rate of 2 pounds to 4 gallons of water. If the insects are sprayed just after they have molted these insecticides almost invariably kill them. It is obvious that further experimentation is desirable along this line.

*Other remedies.*—A few words should be said of other remedies and may be prefaced with the remark that since the harlequin cabbage bug feeds exclusively by *suction* and does not chew its food, the arsenicals, hellebore, and such remedies as are useful against cabbage worms are *absolutely valueless* against the present species. Pyrethrum is not effective and is, moreover, too costly. Hot water applied at a temperature of about 130° F. to the infested cabbage plants should be tested. It is not applicable, however, to large fields on account of the difficulty of maintaining the temperature at a given point, but may be found useful in kitchen gardens.

The value of hand torches for insecticidal purposes is extremely limited. The plumbers' torch is used considerably in Texas as a means of killing this insect, but growers are apt to expect too much of this method, and to apply it to too many kinds of insects, to the ultimate detriment of their crops.

It is possible that some of the natural enemies of this species, especially southern egg parasites, might be utilized in its control; i. e., by shipping parasitized eggs from localities where they are abundant to northern regions in which they do not occur.

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[a] Bul. 89, Texas Agr. Exp. Sta., pp. 9–11, 1907.

SUMMARY.

The general acccount which has been given of this insect in preceding pages has been brought together at this time because of the practical certainty that in the natural course of events this bug will before long endeavor to reinvade territory north of its present range (in 1908), and may again become a pest for a number of years, until climatic conditions adverse to its development or increase check its northward spread.

*In conclusion*, it should be repeated that the systematic destruction of the insects by means of the trap-crop method described, together with a system of clean cultural practice throughout the entire season and especially in the late fall, will leave little else to be done save the gathering by hand of such insects as escape these measures or which may fly from infested to uninfested fields.

*To prevent the pest from advancing farther northward than its present limits, careful watch should be kept for the first appearance of the insect, and remedies should be prompt and thorough.* The importance of killing off the first or hibernated brood of bugs and their progeny can not be too strongly emphasized.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *May 4, 1908.*

[Cir. 103]

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE COMMON RED SPIDER.

(*Tetranychus bimaculatus* Harvey.)[a]

By F. H. CHITTENDEN, Sc. D.,
*In Charge of Truck Crop and Special Insect Investigations.*

### INTRODUCTORY.

One of the most troublesome of greenhouse pests is a minute, reddish, spiderlike creature, known popularly as "red spider." It does very considerable damage in flower and vegetable gardens, and in greenhouses attains its greatest destructiveness. It is particularly injurious to violets and roses, and attacks a great variety of other plants, including shade and fruit trees and some field crops. Beans, cowpeas, eggplant, cucumber, and tomato, especially when grown in hothouses, sustain much injury, while melons, squash, and berries are subject to destructive attack.

Red spiders are not true insects, in fact not even spiders, but are, more properly speaking, spinning mites. Since, however, they are almost universally known as " red spiders," this term is retained.

As the word "mite" indicates, these insects are extremely minute, and when they occur in ordinary numbers are not apt to be noticed unless the leaves are carefully scrutinized. Attention, however, is certain to be drawn to them when they become excessively numerous, as frequently happens in neglected greenhouses or out of doors during droughts in summer.

Red spiders spin threads, but do not, like true spiders, utilize them for climbing or for descending from a height. The threads spun are extremely fine and scarcely perceptible to the unaided eye, but a web

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[a] Until the year 1900 the common red spider, most often occurring in greenhouses, was technically designated as *Tetranychus telarius* L., a name which has been rather indiscriminately applied to all species of red spiders, both in America and abroad.

of threads is frequently so dense as to form a tissue plainly visible at a little distance. Webs are constructed upon the lower side of leaves, and attached here and there to projecting hairs, veins, or the edges of the leaves. Within the webs thus formed the mites feed in their different stages, and the eggs are laid from which the young develop.

### DESCRIPTIVE.

The general appearance of this red spider as seen under a microscope is well shown in figure 1, *a*. At *b* a greatly enlarged palpus of the same species is illustrated, and *c* shows the claws, similarly enlarged.

The length of full-grown individuals, including the palpus, is about $\frac{1}{50}$ inch (0.4 to 0.6 $^{mm}$), and the width about $\frac{1}{100}$ inch (0.25 to 0.30 $^{mm}$), the thickness being 0.17 to 0.20 $^{mm}$. The form is broadly oval, the width greatest in the anterior third of the body, back of the eyes, where the sides are somewhat distended. The general color of the adult is reddish, usually more or less tinged with yellowish or orange, and most specimens have a dark spot on each side, due to the food contents of the body, from which the scientific name *bimaculatus* (two-spotted) has been derived.

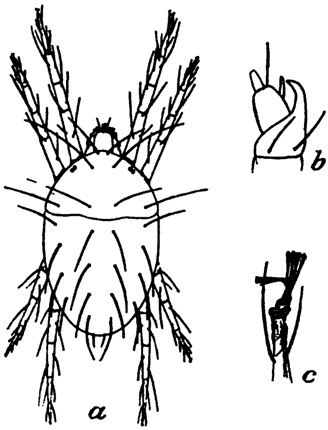

FIG. 1.—The common red spider (*Tetranychus bimaculatus*): *a*, Adult; *b*, palpus; *c*, claws. *a*, Greatly enlarged; *b*, *c*, still more enlarged. (After Banks.)

Careful study of different individuals as they occur on garden vegetables and on horticultural and other plants growing in the field with those taken in greenhouses shows no appreciable differences. According to Mr. Nathan Banks, specimens taken in Florida on Datura and at Washington, D. C., on violets are red, while those from Orono, Maine, and those from the District of Columbia on squash and peach, and on rose from Idaho, are greenish with more or less dark markings.

The eggs are extremely minute, spherical, of variable diameter, glassy, and are scattered and loosely attached about the webs.

The young are somewhat similar in appearance to the adults, but differ in having only three pairs of legs, while the adult has four pairs.

### DISTRIBUTION.

This red spider is well distributed throughout the eastern United States, and was identified as occurring as far west as Idaho in 1900. In 1902 it was recognized from Brighton, Wash.; in 1907 from south-

ern California; and in 1908 at Brownsville, Tex., this last locality practically assuring its occurrence in Mexico.[a]

## NATURE OF INJURY.

The red spider occurs in greenhouses throughout the year, and appears to be at all times destructive if permitted to propagate. Few plants are, in fact, free from its attack, and it is found in most greenhouses. When only a few mites are present the plants seldom show any external evidences of injury, but as they increase in number the leaves gradually turn paler and become yellowish and stunted, and soon the whole plant succumbs unless the proper remedies are applied. Cuttings or young rooted plants are particularly subject to serious injury, and this is especially true in the spring. At this time the mites multiply rapidly, and unless plants are carefully watched they are apt to become so badly infested that it is only with extreme difficulty that they can be restored to their normal growing condition.

The mites injure plants by suction, and when they occur in numbers, which they almost assuredly do when plants are neglected, the vitality of the plants is slowly but surely reduced by the loss of the juices, and in time all of the plants' functions are more or less deranged. In cases of severe attack, millions of red spiders can be found upon the foliage, and the webs, rarely observable at ordinary times, sometimes stretch from plant to plant, the mites passing rapidly over them and congregating in swarms.

## FOOD PLANTS.

The red spider is nearly omnivorous, attacking a wide range of both glabrous and hirsute plants belonging to many families. It has been observed on plants of the following list: Among greenhouse and other ornamental plants, roses, violets, carnations or pinks, mignonette, clematis, pelargonium, abutilon, fuschia, passiflora, manettia, bouvardia, feverfew, verbena, heliotrope, salvia or sage, morning-glory, moonflower, cypress-vine, phlox, chrysanthemum, calla, Easter lily, Boston smilax, mimulus, slipper flower (Calceolaria), canary bird (*Tropæolium peregrinum*), thunbergia, wedding bells (*Brugmansia arborea*), castor-oil plant, *Asparagoides plumosa*, cuphea, godelia, sunflower, and aster. Of the plants listed, violets and roses are very susceptible to damage by the red spider, more especially when the plants are growing under glass.

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[a] If, as seems probable, *Tetranychus cucumeris* or some other species described by Boisduval (Entom. Horticole) is identical with *T. bimaculatus*, it is quite likely that this red spider is of foreign origin and introduced into the United States, which is true of a very large proportion of greenhouse and other indoor insects.

Among truck and vegetable crops, leguminous plants are greatly injured, more especially beans, including Lima beans. Cucumbers and tomatoes grown in hothouses, cantaloupes or muskmelons, watermelons, and squash are also badly damaged. Eggplant, pepper, pepino (*Solanum muricatum*), corn, cowpeas, raspberry, strawberry, beets, and celery are also subject to attack, but are not as a general rule very seriously injured.

Of field crops infested other than those which have been mentioned are hops, hemp, peanut, and the groundnut or wild bean (*Apios apios*).

Trees grown for shade and for fruit are subject to attack and considerable injury is effected at times. The list of trees that have come under observation as subject to the greatest injury includes the Kentucky coffee tree (*Gymnocladus canadensis*), the hop tree (*Ptelea trifoliata*), pecan, ornamental sassafras, arborvitæ, maple, horse-chestnut, and birch.

### INJURY TO TRUCK CROPS.

Every year this species is noted in considerable numbers on the underside of leaves of bean in and about the District of Columbia, frequently causing great blotches and the withering of a large portion of the leaf. When the mites occur in such abundance it necessarily causes a drain on the vitality of the plant and a decrease in the productiveness of seed-pods if not of the seeds themselves. Still, as a rule, such injury is rarely noticed until comparatively late in the season, in September and October.

Similar injury has been reported in Georgia and South Carolina to all forms of beans—snap, butter, and Lima—as well as to cowpeas. In the same States injury has been reported to a variety of other truck crops. Writing in June, one of our correspondents stated that his cucumbers looked as if a blight were on them; another wrote: "A fine garden three weeks ago now looks as if a fire had struck it."

### INJURY TO TREES.

Injury by the red spider to shade and fruit trees is insignificant, as a rule, compared with that which is accomplished by leaf-feeders such as caterpillars. Sometimes, however, very considerable defoliation is caused by the attack of this species. This was very noticeable during the summer of 1906, when the foliage of various shade trees in the city of Washington was injured. Attack was first observed during the third week in July and was manifested by the leaves having turned yellow on the upper surface. The leaves on the lower branches showed the presence of numerous feeding colonies. The Kentucky coffee tree suffered most of all of our city trees. On one of these trees the leaves continued to drop throughout the remainder of July and August, but by September, partly owing to an unprecedented rainfall of three weeks' duration, the mites were less in evi-

dence and many branches from which the leaves had fallen developed new clusters of fresh leaves.

Two years later it was noticed that many of the lower branches which had suffered most from defoliation by the red spider were dead,

FIG. 2.—Kentucky coffee tree, showing partial defoliation by the red spider on lower branches; upper branches have put out new leaves. (Original.)

without doubt owing to the attack of this insect. The accompanying illustration (fig. 2) was taken after the new leaves had become well

developed. Two or three weeks before that time the lower half of the tree bore only a few leaves.

This same form of injury was repeated in 1908, the tree looking considerably worse than shown in figure 2.

### NATURAL ENEMIES.

The predaceous and parasitic insect enemies of the red spider, mentioned below, were observed by the writer on the Kentucky coffee tree at Washington, D. C., during July and early August, 1906.

*Scymnus punctum* Lec., a very small black ladybird, was observed July 21, chiefly as a nearly full-grown larva, and was the most active natural enemy. At that time it was for the most part attached to the leaves for pupation, and a single pupa was found then and many a few days later. Nearly all the larvæ had transformed and the beetles had begun to issue by the 1st of September. An illustrated account of this species was given by J. C. Duffey in 1891.[a]

*Cecidomyia coccidarum* Ckll. (?).—The larva of this small cecidomyiid fly was reared at Washington, where it was fairly abundant. It was secondary in importance only to the ladybird mentioned, as a destroyer of its red-spider host.

With the latter was reared a minute chalcis fly, *Aphanogmus varipes* Ashm., a species recorded as parasitic on cecidomyiids.

*Chrysopa rufilabris* Burm., a lacewing fly, was also reared and the larva was observed in numbers attacking the red spider.

*Thrips sexmaculata* Perg. has been recorded as an enemy of the red spider by Pergande[b] and by Duffey.

### METHODS OF CONTROL.

#### DIRECT REMEDIES.

Red spiders are more resistant to fumigation, either with tobacco or hydrocyanic-acid gas, than are aphides, thrips, and small forms of insects generally. Only a portion of these creatures are usually killed by the ordinary use of the gas in greenhouses—never more than 80 per cent, so far as our records go. The remainder may be stupefied for a time, but eventually recover. They are, however, extremely sensitive to sulphur, applied either dry or as a wash, or in connection with other poisons. Soap is also a good remedy.

*Sulphur.*—Flowers of sulphur, mixed with water at the rate of an ounce to a gallon, and sprayed over infested plants, is of great value in the eradication of this pest; or the sulphur may be combined with strong soapsuds. For the application of this spray a force pump with spraying nozzle is a necessity and *the current should always be directed to the lower surface of the leaves.*

*Soap solutions.*—Potash, fish-oil, whale-oil, and other soap solutions are valuable against the red spider, and the addition of sulphur in-

[a] Trans. St. Louis Acad. Sci., Vol. V, pp. 540–542.    [b] Psyche, Vol. III, p. 381, 1882.

creases their effectiveness; but these washes will injure some delicate plants. Moreover, they have no more value as insecticides than neutral soaps of the castile and Ivory type, or such as are used by physicians and surgeons.

For the red spider, as it occurs in greenhouses, particularly on plants, such as violets, that are liable to injury from sulphur, no other remedy is employed by florists generally than frequent syringing or spraying with water or with a soap solution. Neutral soaps are valuable, particularly upon cuttings affected with the red spider, and the best results have been obtained in the proportion of a 5-cent cake to 6 or 7 gallons of water. The soap is shaved with a small plane, dissolved in about a gallon of hot water, and then sufficient cold water is added to make the quantity desired. Five gallons are sufficient for the treatment of three or four thousand cuttings of violets. It is customary to allow the soap to remain on the plants two or three hours and then to syringe thoroughly with clear water, repeating this treatment two or three times, until the "spiders" and their eggs have been destroyed. Used thus, the soap has little if any deleterious effect upon most plants.

*Kerosene-soap emulsion.*—An emulsion may be prepared by combining 2 gallons of kerosene and one-half pound of whale-oil soap (or 1 quart of soft soap) with 1 gallon of water. The soap is dissolved in boiling water and then poured while still boiling hot (away from the fire) into the kerosene. The mixture is churned rapidly for five or ten minutes, pumping the liquid back upon itself by means of a force pump and direct-discharge nozzle throwing a strong stream. At the end of this time the mixture will have the consistency of thick cream. Properly prepared, an emulsion will keep almost indefinitely, and should be diluted as needed for use. For the red spider the staple emulsion should be diluted with about 10 parts of water. In the preparation of kerosene emulsion a force pump is required, since if not made according to directions a perfect emulsion is not formed and there is then danger of injury to the plants or useless waste. There is danger and waste, too, if the insecticide is not applied by means of a fine nozzle in the form of a *spray*, which should be fine and mist-like. It should be sprayed only for a sufficient time to cover the plants; otherwise the liquid forms into globules and runs off. An elbow attachment for underspraying is shown in figure 3.

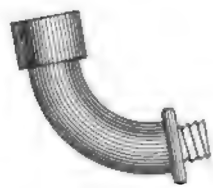

FIG. 3.—Elbow attachment for underspraying. Reduced.

*Lye-sulphur.*—The lye-sulphur remedy was given a thorough test against the red spider in its occurrence on beans in Florida, having been applied May 28, 1908, with the result that 98 per cent of the red spiders were killed without in the least affecting the plants treated.

This shows better results than with any of the four insecticides which were tested in that locality by Mr. H. M. Russell,[a] 3 per cent more of the mites being destroyed than by the use of kerosene emulsion, which slightly injured the plants; 7 per cent more than with the use of sulphur water, and it proved to be much better than lime-sulphur, which was hardly a success as compared with the others. Lye-sulphur is prepared as follows:

Mix 20 pounds of flowers of sulphur into a paste with cold water; then add 10 pounds of pulverized caustic soda (98 per cent). The dissolving lye will boil and liquefy the sulphur. Water must be added from time to time to prevent burning, until a concentrated solution of 20 gallons is obtained. Two gallons of this is sufficient for 50 gallons of spray, giving a strength of 2 pounds of sulphur and 1 of lye to 50 gallons of water. An even stronger application can be made without danger to the foliage. This mixture can also be used in combination with other insecticides (Marlatt, Farmers' Bulletin 172).

*Tobacco water.*—Tobacco water is of some use for destroying the red spider, but can not be recommended for violets, owing to its tendency to weaken the foliage and induce "spot."

*Water.*—Spraying with water is usually practiced two or three times a week during the growing season, and by a little practice and experiment with a fine-spray nozzle or tip the operator is soon able to ascertain the proper degree of force to use. A pressure of about 25 pounds has proved most effective against this red spider. Care should be exercised to wash off the "spiders" and at the same time to avoid drenching the beds. When it is necessary to spray during winter, work should be done on a bright day, in order that the plants may dry off in a few hours. Water is also of use on shade trees and shrubs in parks.

### NOZZLE AND TIP FOR GREENHOUSE USE.

Since the general adoption of spraying as a remedy for the red spider, the problem of how to apply a water or other spray so as not to drench the beds has been an important one. To accomplish this object, Dr. B. T. Galloway, Chief of the Bureau of Plant Industry, has devised a small spraying tip which answers the purpose admirably, being particularly serviceable where plants are syringed or sprayed on a large scale. The following description of the nozzle is taken from Circular 17 of the Division of Vegetable Physiology and Pathology:

The spray tip proper is attached to a brass fitting, which in turn screws onto the end of a three-quarter-inch hose. The apparatus is very effective for spraying roses, as it readily serves to keep the leaves in a thoroughly healthy condi-

[a] For particulars see article by H. M. Russell in Journal of Economic Entomology, Vol. I, pp. 377–380, 1908.

tion, and at the same time wets the beds but little. It is also very useful for violets, as with a pressure of 35 to 40 pounds the leaves of the plant can be readily turned over and thoroughly washed without soaking the crowns and the bed. In spraying some plants, particularly violets, it has been found advantageous to use a lance 18 inches long, made of a piece of one-half-inch brass pipe. This increases the reach, and enables the operator to place the water to better advantage on plants which under ordinary conditions would be beyond arm's length. The apparatus can be made for 50 cents, and will be found a useful instrument wherever there is sufficient water pressure to insure a proper amount of force.

The illustration here presented (fig. 4) shows the general appearance of this tip and nozzle. The nozzle consists of a casting turned to the desired length and flattened at the end as figured. Through this flattened end a narrow slit is made, which should be absolutely true throughout, so that the water as it issues will be broken up into streams. It is even sometimes necessary to file the tips as they come from the factory, to secure the desired result.

#### TREATMENT OF TREES AND SHRUBS.

The methods of control which have been advised above are especially adapted to the treatment of greenhouses infested by the spider. All of the insecticides which have been recommended for indoor use are also applicable to trees and shrubs, the list including sulphur, which may be applied in the form of a powder by means of a powder bellows, or mixed with water as previously prescribed, or combined with lye or lime. Soap solutions, kerosene emulsion, and cold water may be used with profit. Resin wash and lime-sulphur are also used as for the orange mites or red spiders. Of these the lye-sulphur mixture is probably the best, as it is successfully used against these pests in California.

FIG. 4.—Nozzle and tip for greenhouse use. Reduced.

The sulphur treatment has an advantage, in that it adheres more closely to the leaves than other preparations which have been mentioned and kills young mites coming in contact with it as soon as they are hatched. Sulphur preparations are also of value in eradicating scale-insects which might be present at the same time; in fact, when the sulphur is being applied for scale-insects, red spiders or mites are likewise killed.

#### TREATMENT OF TRUCK AND GARDEN PLANTS.

In the treatment of truck crops infested by the red spider, little variation from the methods already advised for greenhouse work need be practiced. The same applies to ornamental flowering plants

in gardens. Considering the great susceptibility to damage from red spider of beans, cowpeas, and other leguminous crops, and ornamental plants, it is advisable, where this mite is very destructive, as in the District of Columbia and southward, to practice rotation with plants not so subject to injury. The lye-sulphur remedy has produced the best results, as just described. Some of the remedial measures advised for the cotton red spider (*Tetranychus gloveri* Bks.), a related species occurring in the Gulf region, may be followed; indeed, the same measures are applicable to aphides and other pests which may be present on the plants at the same time.

Among cultural methods of control may be mentioned clean gardening or farming with early fall plowing, keeping down the weeds of the vicinity throughout the year, and destroying crop remnants as early as possible by burning or otherwise. Weeds growing on the edges of fields, in fence corners, and like locations should be destroyed early in the fall in order that no winter shelter may be left for the pests. Early fall plowing destroys the insects before they have an opportunity to leave the old crop plants for weeds and others.

During May, 1908, Mr. H. M. Russell, working under the writer's direction at Orlando, Fla., conducted some experiments with remedies against the red spider in its occurrence on wax beans. The results obtained, in brief, are as follows:

| | |
|---|---|
| Kerosene-soap emulsion, 1 part stock solution to 10 parts water, killed | 95 per cent. |
| Lye-sulphur, 1 pound sulphur, ½ pound lye, to 40 gallons water, killed | 98 per cent. |
| Sulphur water, 1 ounce to 1 gallon water, killed | 91 per cent. |
| Lime-sulphur, 1 pound lime, 1 pound sulphur, to 25 gallons water, killed | 68 to 85 per cent. |

The results show that the red spider succumbs to any one of these four insecticides, the probabilities being that kerosene-soap emulsion, properly prepared and applied, is as satisfactory a remedy as any other applications that could be employed.

## SUMMARY.

The remedies advised may be summarized as follows:

For the greenhouse and for general use, sulphur and neutral, whale-oil, and other soap solutions, kerosene-soap emulsion, and spraying with water.

For the treatment of trees and shrubs, the same as the above, with the addition of resin wash and the lime-sulphur and lye-sulphur mixtures.

For truck and garden plants, lye-sulphur wash and the same remedies as for the greenhouse, with the addition of clean gardening

or farming, early fall plowing, keeping down weeds, and crop rotation where practicable.

Finally, it should be stated that unless remedial measures be adopted and thoroughly and repeatedly applied as often as necessity demands, the red spider is almost certain to do permanent harm to delicate plants, since as soon as the plants become badly infested they seldom, if ever, fully recover.

Approved:
JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *November 30, 1908.*

[Cir. 104]

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CIRCULAR No. 105. Issued October 5, 1908.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE ROSE SLUGS.

By F. H. CHITTENDEN,
*In Charge of Truck Crop and Special Insect Investigations.*

Roses grown in gardens in the United States are attacked by three species of sawflies which live, in their larval stages, on the foliage, skeletonizing the leaves or cutting out holes of variable size and greatly disfiguring the plants. The larvæ, popularly known as "rose slugs," "slugworms," and "roseworms," have been classified as the American rose slug, the bristly roseworm, and the coiled or curled roseworm, respectively. For the sake of uniformity they may all be called rose slugs. The first of these, as its common name indicates, is native to America; the other two are evidently accidental introductions from Europe, as they are now common to both hemispheres. As with most other sawflies,[a] they are found more abundantly in the North, but are quite troublesome as far southward as Maryland and Kansas. They practically confine their depredations to the flower garden, and roses are the only plants that are seriously damaged by them. Injury is due entirely to the larvæ, and the three species, each representing a distinct genus, differ considerably in appearance in all stages, as also in their life history and manner of work.

## THE AMERICAN ROSE SLUG.

(*Endelomyia rosæ* Harr.)[b]

The American rose slug was first identified as a pest about the year 1831, when it did damage in gardens at Cambridge, Mass. At that time the species was somewhat restricted to that locality, but later, according to Harris, who observed and studied its habits,[c] it gradually spread in that vicinity and by 1840 it had become so great a nuisance that a premium of $100 was offered for the most successful method of destroying it.

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[a] Hymenopterous insects of the family Tenthredinidæ.

[b] Synonyms: *Monostegia rosæ* and *Selandria rosæ*.

[c] Report Ins. of Mass. Inj. to Veget., 1841, pp. 380–382; Flint ed., pp. 525–528.

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DESCRIPTIVE.

The sawfly which produces the American rose slug is a four-winged bee-like insect (fig. 1, *a*) of a deep shining black color, with translucent smoky wings having dark-brown veins and a brown spot near the middle of the edge of the forewings. The wing expanse of the female is about two-fifths of an inch and the length of the body is fully one-fifth of an inch. The male is a little smaller.

The larva or slug (*b*, figs. 1, 2) when full grown is about one-third of an inch long and sluglike, with the thoracic joints enlarged. The

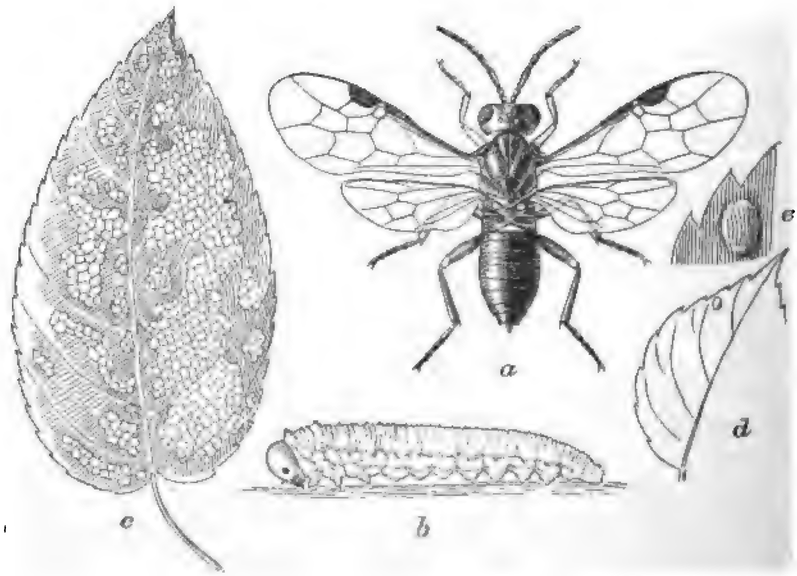


FIG. 1.—American rose slug (*Endelomyia rosæ*): *a*, Adult sawfly; *b*, mature larva; *c*, work of larvæ on rose leaf; *d*, section of rose leaf, showing location of egg near upper margin; *e*, egg in situ on bit of rose leaf. *a*, *b*, *e*, Much enlarged; *c*, less enlarged; *d*, about natural size. (Original.)

body is soft and delicate, but not gelatinous and slimy, as is the case with some sawfly larvæ—for example, the pear slug. The color is green above and yellowish on the lower surface. The head (fig. 2, *c*) is small, oval, and yellowish, and has a black spot on each side, inclosing the eye.

DISTRIBUTION.

The assertion has been made by Riley [a] that this sawfly undoubtedly originated in New England, where it fed upon wild rose. With the lapse of years, if we assume this statement to be correct, it has been disseminated by commerce into neighboring States and through the

[a] American Entomologist, Vol. III, 1880, p. 115.

importation of rose bushes from eastern nurseries to western gardens. Owing to the sluggish habits of the female, its distribution by flight has undoubtedly been very slow. Its occurrence in New York, New Jersey, Ohio, Illinois, Michigan, and Missouri has been known for a number of years, and it undoubtedly occupies intervening States.

In 1904 we received reports of injuries by it in Pennsylvania, New York, Maryland, and Kansas; in that year it also appeared at Charlottesville, Va., and the following May reached the District of Columbia, where it has been quite abundant since. In 1908 it was reported injurious at Cincinnati, Ohio.

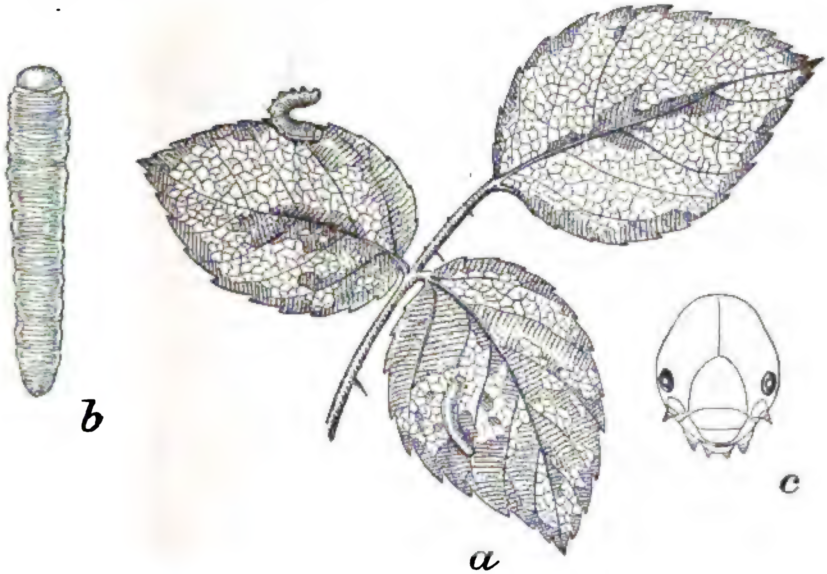


FIG. 2.—American rose slug (*Endelomyia rosæ*): *a*, Larvæ, natural size, upper larva at work on upper surface of leaf, lower larva at rest on under surface; *b*, larva, dorsal view, enlarged; *c*, head of larva, more enlarged. (Original.)

## LIFE HISTORY.

The parent sawflies issue from the earth at varying times from about the 1st of April, or earlier in the District of Columbia, to the third week in May, or, according to Harris, until the middle of June in Massachusetts, beginning at about the time when the roses first unfold their leaves and continuing until they are in full leaf. During this period pairing takes place and eggs are deposited. The females are particularly sluggish in the cool of morning and are not often seen in flight, resting during the greater part of the day on the leaves. When disturbed they draw up their legs and fall to the ground. The males, however, are quite lively, flying from one rose bush to another and hovering around their less active partners.

The female in depositing her eggs turns a little to one side, unsheaths her delicate saw-like ovipositor, and thrusts it between the two cuticles of a leaf, depositing a single egg in each incision. An egg is shown about natural size at *d*, figure 1, and much enlarged at *e*. The egg is of circular outline, much flattened, and measures about one-twentieth of an inch in diameter. Hatching begins in from ten days to two weeks after the eggs are deposited.

The larvæ or slugs are to be found at work as early as the 1st of May in the District of Columbia, but their appearance in numbers is seldom noticed until the second or third week of that month. Observations conducted at Washington, D. C., show that the periods mentioned are subject to considerable variation. In 1905 the first sawflies of the new generation appeared June 2. Owing to the irregularity of appearance of the parent "flies," larvæ of the first generation may be found at work for a period of five or six weeks. Feeding takes place chiefly at night, and always on the upper surface of the leaves, the lower surface, ribs, and midribs remaining as a skeleton (fig. 1, *c*). The leaves are practically always skeletonized, not eaten into as in the case of the other two rose slugs, except when the larvæ are nearly grown. During the daytime the larva usually rests concealed on the under surface of a leaf (fig. 2, *a*).

Sometimes the larvæ are so abundant that not a leaf on a bush is spared, and the foliage looks as though it had been scorched by fire, and eventually drops off. The larvæ are stated to be between two and three weeks in attaining their growth. They cast their skins several times, leaving them fastened to the leaves. After the last molting they lose their greenish hue and become opaque yellowish. They then descend into the earth to a depth of an inch or more, and each constructs for final transformation a somewhat fragile oval cell or cocoon coated with particles of earth. Here the insect remains as larva until the following spring, when it transforms to pupa shortly before issuance in May.

The species is single-brooded, in which respect it resembles many other species of sawflies.[a]

### REMEDIES.

This rose slug and the others which will be discussed are quite easily controlled by several different methods.

*Sprinkling with water.*—A strong stream of water directed upon the plants from different sides by an ordinary garden hose or large

[a] It is evident from Harris's account (l. c.) that in ascribing two generations to this rose slug he must also have had the bristly rose slug under observation. Miss M. E. Murtfeldt writes on this head that she has disproved Harris's statement "by repeated rearing of the insect under close observation." (41st Annual Rept. State Hort. Soc. Missouri, 1898, p. 288.)

syringe, if applied every day or two, will soon rid rosebushes of the pest. This is at the same time an excellent remedy for rose aphides or plant-lice. The insects are dislodged, fall to the ground, and are unable to return to reinfest the bushes. This remedy was tested practically by Dr. L. O. Howard many years ago.

*Paris green.*—Where it is possible to apply them without danger of poisoning human beings or disfiguring the plants for ornament, different poisonous preparations are useful. Of these, Paris green, either dry or in solution, arsenate of lead, and white hellebore are good remedies. Paris green is best used as a spray in the proportion of an ounce to a gallon of water. Applied dry, it is mixed with 20 parts of flour or similar diluent and puffed on the plants by means of a powder bellows or insufflator. For use in large gardens, however, the poison is employed at the rate of 1 pound to from 75 to 125 gallons of water, lime being added in about the same proportion as Paris green to prevent scorching. For properly mixing and applying this insecticide a sprayer of good quality should be used. Sprinkling with a watering pot or with a whisk broom will not answer the purpose and is, moreover, dangerous to tender foliage. The Paris green is first mixed with a small quantity of water into a fine paste before the bulk of water is added and should be churned in the sprayer or force pump until thoroughly blended. The resulting mixture, being a mechanical one, is not constant and the arsenical sinks to the bottom. The solution should therefore be constantly stirred while being applied in order that an even application may be made. In applying an arsenical spray an effort should be made to reach all of the leaves, which may be accomplished by spraying from two sides. Two or three applications will suffice for the spring generation of rose slugs. Scheele's green and some other arsenicals can be used instead of Paris green.

*Arsenate of lead.*—A still more valuable insecticide for such insects as rose slugs and other leaf feeders is arsenate of lead, but its use is open to the objection that it discolors the leafage, leaving a white deposit, which is not, however, permanent. It is applied in practically the same manner as Paris green and is a less poisonous arsenical, and, being sold in paste form, is used at a considerably greater strength—about 1 pound combined with 15 to 25 gallons of water or Bordeaux mixture. Being adhesive, it adheres more firmly to the leafage and is much less likely to produce scorching.[a]

*Hellebore.*—Hellebore is used at the rate of 1 ounce to from 2 to 3 gallons of water, and kills by contact as well as by its poisonous effects

[a] Additional information in regard to the preparation and use of arsenate of lead and other insecticides is given in Farmers' Bulletin 127, which may be had gratis on application to the U. S. Department of Agriculture.

when eaten by the insect. It is less poisonous to man than an arsenical, but not so effective to leaf-feeding larvæ. It may also be applied dry mixed with about double its weight, or more, of powdered plaster or cheap flour.

When not in use the receptacles containing poisons should be plainly labeled "Poison!" and placed on a high shelf or in a locker out of the reach of children. Properly applied, there is no danger, in using an arsenical on ornamental plants, of poisoning human beings, or domestic animals other than rabbits or similar pets.

*Soaps and other washes.*—Oily soaps, such as fish-oil or whale-oil soap, and other soaps, and tobacco water will kill these insects, but their use is open to the objection that if applied just before or at blossoming they are apt to injure the petals of delicate flowers, and whale-oil and tobacco also leave an unpleasant odor. A neutral soap, such as castile or that used by physicians and surgeons, leaves no odor.

*Dry powders.*—Fine, sifted road dust, where this can be readily procured, is also of value thrown upon the plants, preferably by means of a powder bellows, as it closes the breathing pores of the larvæ and thus kills them. Finely powdered lime, and buhach (Persian insect powder, or pyrethrum) are also effective.

*Hand picking.*—If rose slugs are picked off by hand upon their earliest appearance this will greatly reduce their numbers for the following year. In the adult or "fly" stage these insects may be easily captured by hand on cool mornings. Hand picking may be tedious, but it is effective.

*Fall cultivating.*—If other means that have been specified have not been utilized for the suppression of the slugs, many individuals may be destroyed by frequent cultivation of the soil between the rose plants during the late summer and autumn. This has the effect of breaking up their pupal cells and otherwise disturbing the insects so as to interfere with proper hibernation.

## THE BRISTLY ROSE SLUG.

(*Cladius pectinicornis* Fourcr.)

The bristly rose slug, called also the spiny rose slug, is the principal enemy of the rose in and near the District of Columbia, not excepting the rose-chafer. It is believed to have been brought in from Europe some time prior to 1833, since it was mentioned by Harris in his catalogue of Massachusetts insects of that date. In the early seventies it was reported from Connecticut and in after years it made its way westward and southward, doing more or less injury whereever established. Since 1880 it has done much mischief in Wash-

ington, D. C. In 1886 it was reported from Lafayette, Ind. In 1889 it was observed to be injurious at St. Charles, Mo. Soon afterwards it was recognized as a pest at St. Louis, where it attracted considerable attention.

### DESCRIPTION AND DISTRIBUTION.

The adult of this species (fig. 3, *a*) differs considerably from that of the American rose slug, as will be readily seen by a comparison of the illustrations of the two forms. It is a larger insect and a member of a different genus. The wing expanse is about one-half of an inch for the female; a little shorter for the male. The ground color is black. The antennæ are rather stout and acutely pointed, and in

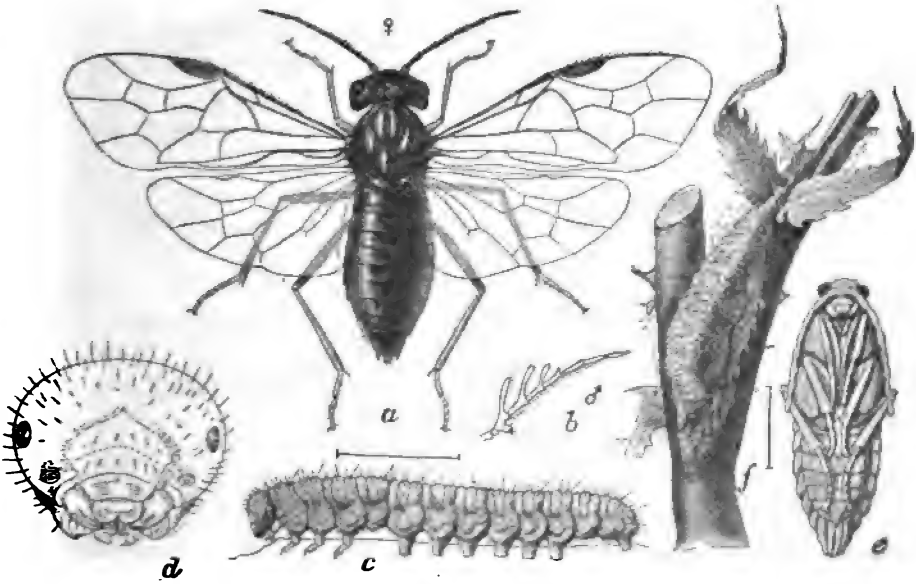

FIG. 3.—Bristly rose slug (*Cladius pectinicornis*): *a*, Adult female; *b*, antenna of male; *c*, larva; *d*, head of same; *e*, female pupa; *f*, cocoon. All enlarged. (Reengraved after Riley, except *d*, original.

the male the proximal joints, or those nearest the head, are pectinate or comb-toothed (fig. 3, *b*), which has given rise to the specific name *pectinicornis*.

The egg (fig. 4, *a*) is white, flattened, rounded, stoutest at the anterior end, and more pointed at the opposite end. It measures about 0.8 mm. in length.

The larva or slug, shown in figure 3, *c*, and figure 4, *c*, *d*, varies from yellowish to glaucous green, and the whole surface is quite bristly, especially at the sides, a character from which this larva derives its common name and which will distinguish it from the other two that feed upon the rose. The length when full grown is a little

more than three-fifths of an inch and the diameter is between one-tenth and two-tenths of an inch.

The pupa (fig. 3, *e*) is grayish green, the thorax and end of the body are slightly yellowish, and the antennæ, wing-sheaths, and legs are white with a slight greenish tinge.[a]

The distribution includes the States of Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, the District of Columbia, Indiana, Illinois, and Missouri.

It is generally distributed on the continent of Europe and occurs also in England and Scotland.

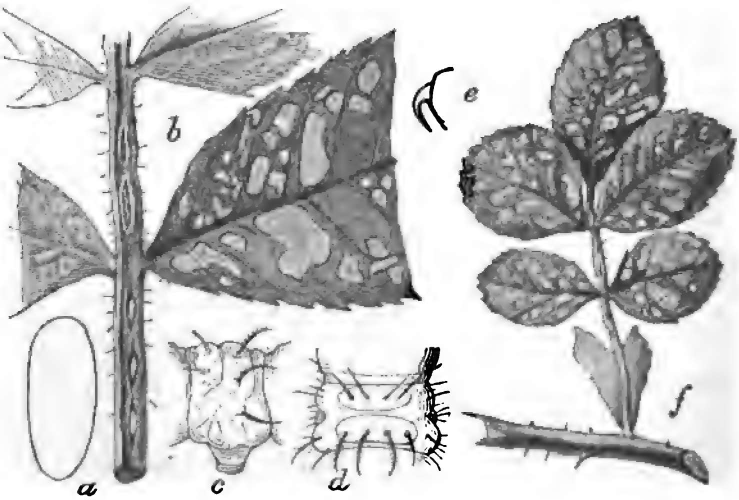


FIG. 4.—Bristly rose slug (*Cladius pectinicornis*): *a*, Egg; *b*, portion of leaf showing eggs in situ and work of young larvæ: *c*, *d*, lateral and dorsal aspects of middle segment of newly hatched larva; *e*, larval claw; *f*, rose leaf showing nature of defoliation. All except *f* enlarged. (Reengraved after Riley.)

## LIFE HISTORY.

The bristly rose slug differs considerably from the preceding in its life economy. Its appearance at Washington, D. C., and at St. Louis, Mo., has been observed from the latter days of April to the third week of May, beginning about the time that the first rose leaves are put forth. Its eggs are inserted in the upper surface of the petiole of the leaf and are deposited in rows of three or more together.

The slug in its earliest stage skeletonizes the leaves, leaving whitish blotches and small holes (fig. 4, *f*), but with increased growth it eats large, irregular holes in the leaf (fig. 4, *b*), devouring the entire sub-

[a] More detailed descriptions of the stages are furnished in C. V. Riley's article, Insect Life, Vol. V, pp. 6–11, which includes accounts of the other two species here treated.

stance, and frequently leaving nothing but the stronger ribs. While feeding, the slug rests in concealment on the lower surface of a leaf, and does not feed on the upper surface, as does the American rose slug. Upon attaining full growth it does not, like the latter, abandon the plant upon which it has fed until the final generation. Indications are that there may be three and, in some seasons in its southernmost range, perhaps four generations produced each year, larvæ occurring as early as the 1st of May and as late as the 1st of November. In northern Europe two generations are recognized.[a] The larvæ of the earlier generations spin their cocoons (fig. 3, *f*), which are composed partly of silk and partly of a glutinous substance, upon the lower surface of the leaves, or on twigs or near-by objects, usually surrounding them with an irregular fringe. The last or autumn generation forms its cocoons among fallen leaves and other rubbish about the base of the rose bushes.

The egg period in late April and early in May has been observed in the District of Columbia to last for from seven to ten days, and the young larvæ begin feeding in the first and second weeks of May. Larvæ grow rapidly, and cocoons have been found by the middle of May. The pupal period observed was fifteen days, so that the second brood of flies may appear before the end of May. This second generation begins work about the second week in June, but during July there is a comparative cessation, presumably between the second and third broods of worms, when fresh growth is little affected.

Mr. G. Pauls, St. Louis Altenheim, St. Louis, Mo., wrote in regard to observations conducted by him on this species at St. Louis in 1904. The sawfly continued depositing eggs up to September 17. October 14 he placed larvæ in a jar; three transformed to pupæ October 17, 19, and 24 and issued March 30 to April 10 of the following year. One larva pupated October 16 and issued March 22, having passed about five months in the pupal stage. This shows considerable variation in the time of issuing indoors, and would probably be duplicated to a certain extent in the open. April 29 he observed the sawfly depositing eggs on the leaves.

### NATURAL ENEMIES.

No natural enemies of this rose slug appear to have been recognized in America, but in Europe it is preyed upon by two parasites, *Acrotomus lucidulus* Grav. and *Mesochorus cimbicis* Ratz.

[a] Various European authors have written on this species. One of the most accessible general articles is that by M. S. C. Snellen van Vollenhoven, translated from the Dutch by J. W. May and published in The Entomologist, Vol. VIII, 1875, pp. 26–29.

### REMEDIES.

The same remedies advised against the American rose slug are employed against the present species, with the exception of fall cultivation, which is practically useless when applied to it, owing to the fact that the cocoons are formed upon the plants on the surface of the ground and not buried in the earth as with the preceding species. Since there are more than one generation of this slug, sprinkling with water and spraying with poisons must be repeated several times in order to produce the desired results; in short, as often as the insects reappear upon the plants, from April to October, according to locality.

## THE COILED ROSE SLUG.

(*Emphytus cinctus* L.[a])

The third of the rose slugs under consideration, the coiled rose slug, is a comparatively recent importation. As with the two preceding species, it first attracted attention near Boston, Mass., but not until the year 1887.[b] It is probable, however, as in the case of most European insects introduced into this country, that its importation was accomplished at a considerably earlier date. Reasoning from analogy, this insect might have been brought from the mother country on potted roses ten or twenty years earlier than the date specified, as that length of time is sometimes necessary for a foreign insect to become permanently established so as to attract attention by its injuries.

### DESCRIPTION AND DISTRIBUTION.

From the two preceding species this insect may be readily separated on account of its larger size in the adult stage (fig. 5, *a*). It has nearly transparent wings, and a wide band which crosses its shining black abdomen near the middle. The body is comparatively slender, and the head longer than in the other two species. The wing expanse is about five-eighths of an inch and the length of the body about three-eighths of an inch.

The larva when mature is about three-fourths of an inch long and differs notably from the other two species here considered in being perfectly smooth. It is cylindrical and tapers very slightly toward the posterior extremity. The color is metallic green above, ornamented with small white dots, and the lower surface, including the legs, is grayish white. The head (fig. 5, *c*) is yellowish orange, with a dark brownish-black stripe down the middle. The eyes are black.

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[a] *Emphytus cinctipes* Nort. is recognized as a synonym.

[b] J. G. Jack, Garden and Forest, Mar. 26, 1890, pp. 151–152.

The first thoracic segment is blue and the last two are gray.[a] The larva habitually rests in the coiled or curled position shown in figure 5, *b*, one that is never assumed by either of the other rose slugs, and it is from this habit that it derives its English name.

In addition to Boston, it has been authentically reported from Jamaica Plain, Roxbury, and New Bedford, Mass.; portions of Maine; Allegheny, Pa.; New York, and Canada. In the Eastern Hemisphere this species ranges over the major portion of Europe, extending into Siberia.

### NATURAL HISTORY.

The coiled rose slug is credited with being double-brooded, and as it extends its range southward it will probably produce a third generation, since we know of the appearance of the "worm" from May

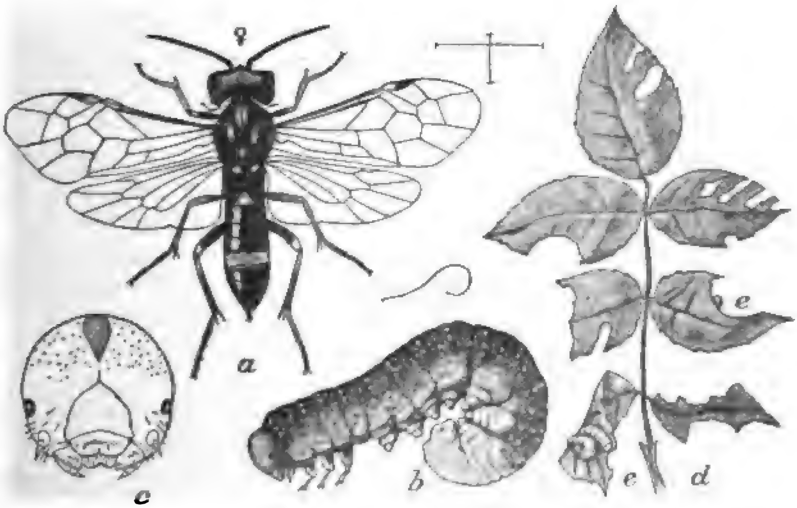


FIG. 5.—Coiled rose slug (*Emphytus cinctus*): *a*, Adult female; *b*, full-grown larva; *c*, head of same; *d*, work on plant; *e*, *e*, young larvæ at work. *d*, *e*, Natural size; *a*, *b*, enlarged; *c*, more enlarged. (Reengraved after Riley.)

to October. Eggs are deposited singly on the underside of the leaves to the observed number of from three to seven. This slug differs from the others in devouring the entire substance of a leaf, feeding along the edges with its body coiled beneath it, and when at rest remaining curled in a ball on the lower surface (see fig. 5, *e*). Upon reaching maturity the slug deserts the leaves and bores into the pith of the stems of dead rose bushes or other available plants, and here the pupal state is passed, the fall generation hibernating to emerge the following May. At Boston, Mass, the adults have also been observed in July, this indicating the first new generation.

[a] A more technical description by Dr. H. G. Dyar is given in the Canadian Entomologist, Vol. XXVI, p. 186.

### NATURAL ENEMIES.

A parasitic enemy of this species was reared by the writer from larvæ received from Allegheny, Pa., in 1904. It issued October 20, and proved to be a tachina fly, *Tachina rustica* Fall.

In Europe an ichneumon fly, *Cryptus emphytorum* Boie., is parasitic upon this sawfly.

### REMEDIES.

The remedies are the same as for the American rose slug, subject, however, to the same changes as for the bristly rose slug.

Approved:

James Wilson,

*Secretary of Agriculture.*

Washington, D. C., *August 4, 1908.*

[Cir. 105]

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CIRCULAR NO. 106. Issued May 13, 1909.

# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE WHEAT STRAWWORM.

(*Isosoma grande* Riley.)

By F. M. WEBSTER,
*In Charge of Cereal and Forage Plant Insect Investigations,*

AND

GEO. I. REEVES,
*Assistant in Cereal and Forage Plant Insect Investigations.*[a]

The wheat strawworm (fig. 1) sustains about the same relations to winter-wheat culture west of the Mississippi River that the joint worm (*Isosoma tritici* Fitch)[b] does to the cultivation of this cereal east of this river. Both, when excessively abundant, occasion losses varying from slight to total. A wheat stem attacked by the jointworm may produce grain of a more or less inferior quality and less of it; but the spring attack of the wheat strawworm (fig. 5) is fatal to the plant affected, as no grain at all is produced; and while the second generation of the same has a less disastrous effect in the field, it nevertheless reduces the grade and weight of the grain.

In the Ohio Valley and south of Pennsylvania the ranges of these two insects overlap (fig. 2); both species are often to be found in the same field, the wheat strawworm, however, being less abundant and doing usually but slight injury, while the jointworm occasionally becomes a serious pest.

FIG. 1. Larva of *Isosoma grande* in wheat straw. (Original.)

[a] During the last two years Mr. Reeves has been engaged in the investigation of this pest in the State of Washington in cooperation with the agricultural experiment station of that State. With the exception of the statements made relative to the behavior of the pest in the Northwest, for which exclusive credit is to be given the junior author, the senior author is responsible for the circular.

[b] See Circular No. 66, Bureau of Entomology, United States Department of Agriculture, 1905.

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West of the Mississippi River, throughout the winter-wheat growing territory, the jointworm, if it occurs at all, is never destructive. The wheat strawworm, on the other hand, appears to be generally distributed, at times committing very serious depredations which have, at least in some cases, been charged to the Hessian fly, as shown by the fact that some of these ravages have occurred in sections where the Hessian fly is not known to exist. Besides, while the Hessian fly is manageable with more or less difficulty, the wheat strawworm is

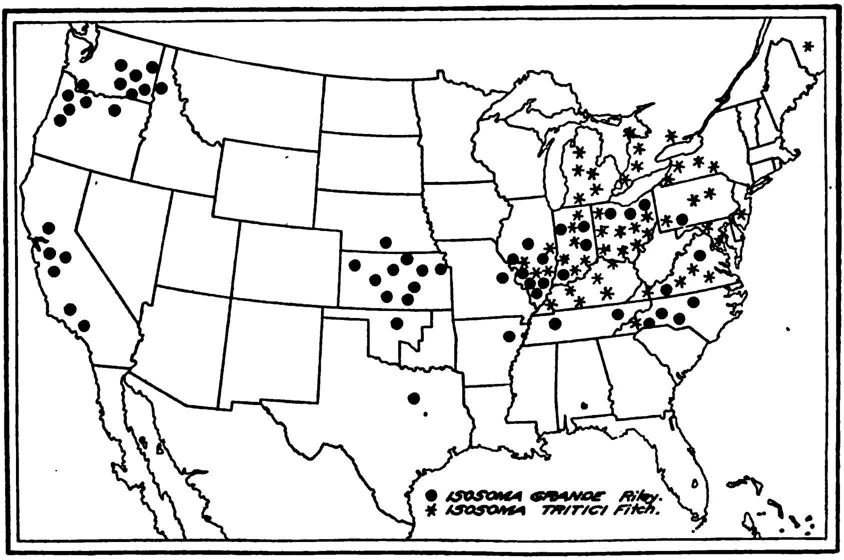


FIG. 2.—Present known distribution of *Isosoma grande* and *Isosoma tritici* in the United States. (Original.)

one of the easiest of all insect pests to control by entirely practical measures. Indeed, it need not be allowed to become a pest at all.

## DESCRIPTIONS AND SEASONAL DEVELOPMENT.

There are two generations of the insect annually, the adults of the first generation (fig. 3) differing considerably in appearance from those of the second (fig. 4). To the farmer they will all look like minute or large, shining black ants, with or without wings, their legs more or less banded with yellow, and having red eyes. Individuals of the first generation emerge in April from the outstanding straws and stubble. They are very small, most of them are females, and many are wingless. The females deposit their eggs in the young wheat plants, the stems of which at this time extend but little above the surface of the ground. The egg is placed in or just below the embryonic wheat head (see fig. 6) and the larva or worm works within the

stem, usually causing a slight enlargement. When the worm is full-grown it will be found in the crown of the plant, having eaten out and totally destroyed the embryonic head, its body occupying the cavity thus formed.

FIG. 3.—Wingless adult of the spring form of *Isosoma grande.* (Original.)

The females (fig. 3) which deposit these eggs, being small and frequently wingless, are in no way fitted for traveling long distances. The larva or worm (fig. 1) is of a very light straw color, indeed almost white, with brown jaws, the form of the body being as shown in the illustration. These worms develop very rapidly and, as they feed on the most nutritious part of the plant, they become robust and larger than those found in the mature straw in late summer. In May the larvæ become full grown (fig. 5) and pass at once through a short pupal stage. (See fig. 7.) The pupæ are at first the same color as the larvæ, but later change to a shining jet black. In a few days the fully developed insects gnaw circular holes through the walls of the stem and make their way out. These adults (fig. 4) are much larger and more robust than the individuals of

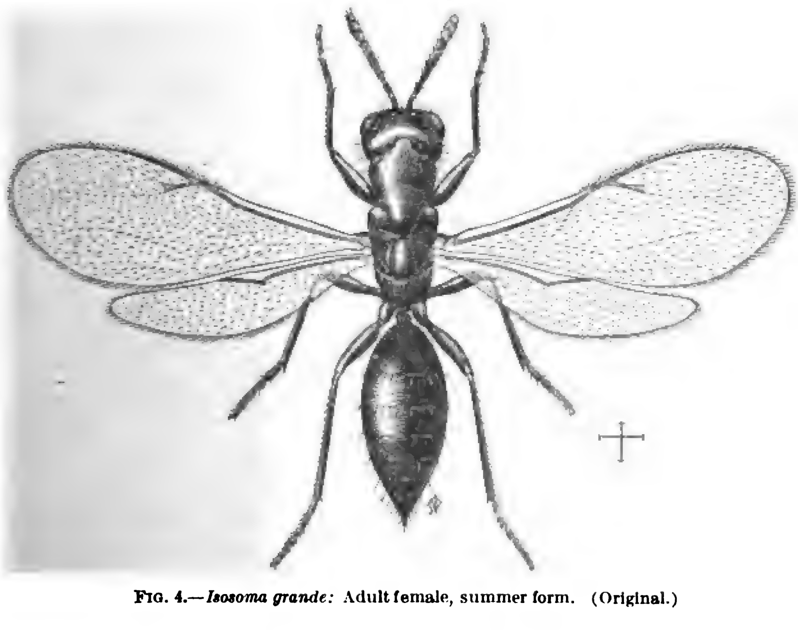

FIG. 4.—*Isosoma grande:* Adult female, summer form. (Original.)

the first generation and are provided with fully developed, serviceable wings. That they make good use of their wings, and scatter themselves about over fields adjacent to their place of development, is

shown by their occurrence in fields of grasses (in the stems of which they do not breed) situated considerable distances from wheat fields. In ovipositing, the females of this generation select the largest and most vigorous-growing stems in which to place their eggs.

The adults of the second generation deposit their eggs from early May, in Texas, up to the middle of June, in northern Indiana, or about the time the wheat is heading. Their aim at this time is to place the eggs singly in the growing stem just above the youngest and most succulent joints, which are not so covered by the enfolding leaf sheaths as to be inaccessible to them (see fig. 8). Thus it is that the stage of advancement in the growth of the wheat stems at the time of oviposition of the summer generation of females determines whether the larvæ will be well upward in the straw, and therefore removed after harvest, or lower down and consequently left in the field in the stubble.

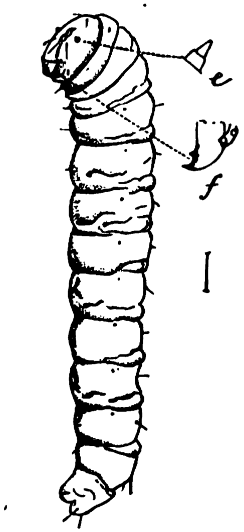

FIG. 5.—Larva of the wheat strawworm (*Isosoma grande*): *e*, Antenna; *f*, jaw. Line at right indicates natural length. (After Riley.)

The method of oviposition and the point where the egg is usually inserted are shown in figure 8. The shape of the egg after being placed in the stem is also shown in the same figure. The larva forms no gall, nor does it harden the stem within which it develops. There is normally but one larva in each joint; but if several eggs have been placed between joints and produce larvæ there will be one in the center of the stem just above the joint and others in the walls just under the internal wall covering or inner epidermis. These larvæ in the walls of the straw do not, as a rule, kill the stem, but their effect is to shrink kernels, curtailing the yield by reducing the weight. The larvæ develop rapidly and reach their full growth before the straw has hardened. By October, in the Middle West, though earlier in the South, they pass into the pupal stage, in which, as a rule, they remain until early spring, whereupon they develop to adults and gnaw their way out.

## HISTORY OF THE SPECIES.

In June, 1880, Mr. J. K. P. Wallace, of Andersonville, Tenn., sent wheat straws containing larvæ of this species to Dr. C. V. Riley, then Government Entomologist, with the statement that nearly every straw in his field was infested by similar larvæ and as a consequence was inclined to fall before the grain had fully ripened. It was from these straws that the types of *Isosoma tritici* Riley were secured. In October, and later on in 1881, Mr. J. G. Barlow, of Cadet, Mo., sent

Doctor Riley many infested straws, from which adults of the spring form were afterwards reared. At Carbondale, Ill., in June, 1882, Prof. G. H. French found the species infesting wheat fields, in some cases 93 per cent of the straws being affected and from one to three larvæ being found in each straw.[a]

September 16, 1882, straws containing pupæ and an occasional larva were received by Doctor Riley from Mr. J. A. Starner, Dayton, Columbia County, Wash. On October 1, 1883, the senior author received infested straws from Stockton, Cal., through Professor French, and from these he was able to rear the spring form of adults during the following February. On May 8, 1884, he found adults abroad in a wheat field near Bloomington, Ill. On May 9 oviposition was observed, larvæ were found in the wheat plants May 28, and a single pupa was found on the following day, all in the same field of growing wheat. Straw taken from this same field early in the following July produced the spring form of this species the following spring—April, 1885.

FIG. 6.—*Isosoma grande:* Showing point where female of the spring form deposits the egg in young wheat in early spring. Enlarged, showing position of egg, at right. (Original.)

At Oxford, Ind., June 6, 1884, the senior author found large winged adults of the summer form ovipositing in the stems of growing wheat, and in a small developed stem like those observed in May, about Bloomington, Ill., a living pupa was found. Straws from the Oxford field gave precisely the same form the following April as did the straw from Bloomington. The larger form, observed at Oxford June 6 and later, was also collected in fields about Bloomington a few days earlier. Larvæ of this larger form were found in wheat fields in southern Illinois in May, and the adults were observed in the same section of country in late May and early June by Prof. H. Garman, at that time assistant to Dr. S. A. Forbes.[b] Doctor Riley de-

[a] Prairie Farmer, July 8, 1882.

[b] Fourteenth Rep. State Ent. Ill., pp. 34–37, 1885.

scribed this larger form as a new species, giving it the name *grande*.[a] During the years 1884 and 1885, however, the senior author reared Riley's *Isosoma tritici* from straws in which only his *I. grande* had oviposited and his *I. grande* from plants to which only *I. tritici* had access. As this last name had been applied by Doctor Fitch many years earlier to another insect, the jointworm, the name *grande* must necessarily be given to both forms.

FIG. 7.—*Isosoma grande:* Pupa of summer form in young wheat. (Original.)

BUREAU NOTES AND OBSERVATIONS BY ASSISTANTS.

Strangely enough, one of the earliest reports of this species came from Mr. J. A. Starner, Dayton, Columbia County, Wash. Infested straws containing a few larvæ, but mostly pupæ, were received September 16, 1882, showing that even at that early date it was sufficiently abundant to attract the attention of farmers. Mr. D. W. Coquillett found it at Anaheim and Atwater, Cal., in 1885, while Mr. Albert Koebele found it during the same year at Folsom, Cal. It was also sent to the Department by Mr. J. F. Donkin, from Grayson, Cal., during the same year. In 1885 Prof. F. H. Snow reported it as doing serious injury in McPherson, Morris, Osborne, Ottawa, and Saline counties, Kans., and mentioned it as a new pest,[b] and in 1891 it was prevalent in central and western Kansas.[c] In 1886 Mr. Coquillett found it at Los Angeles, Cal. During August, 1890, infested straws from Washington State were received at the Department from Moses Bull, Pullman; J. W. Jessup, Rosalia; G. W. Dunn, Tekoa; and Milton Evans, Walla Walla.

[a] Bul. Brooklyn Ent. Soc., 1884, pp. 11-12.
[b] Monthly Rep. Kans. Bd. Agr., June, 1885.
[c] Loc. cit., Feb., 1892.

Although there were no reports of damage in the spring, injury was sufficiently marked to attract the attention of farmers, and from these one frequently hears, even up to the present time, descriptions and reminiscences of what seems to have been the first serious outbreak of the pest in the United States.

The senior author found the species abundant but not destructive at Princeton, Ind., in 1887 and again in 1902. June 27, 1893, infested straws were sent to the Department of Agriculture by Mr. E. J. Woodville, Indiantown, Va. In 1905 the junior author found the species infesting growing wheat about Conway, Ark., April 7, the larvæ being apparently full grown; and at Petty, Tex., April 14, he found larvæ and pupæ present in great numbers, in some cases 50 per cent of the young wheat plants being infested. He also found half-grown larvæ at Concordia, Kans., April 21. During the same year the senior author found larvæ in young wheat at Lexington, N. C., April 12; and at Statesville, N. C., on the following day, he found not only larvæ in the young plants, but females of the spring form in the act of ovipositing. At Charlotte, N. C., April 14, larvæ and pupæ were found abundantly in the young wheat. On the 18th of the same month young larvæ were found in young wheat plants at Dublin, Va. Mr. W. J. Phillips found the species quite numerous in young wheat plants at Nashville, Tenn., April 20, and studied the oviposition of both forms at Richmond, Ind., from May 26 to June 27. June 16 the Bureau received infested straws from Mr. H. W. Joy, Hays, Kans. On May 24 of the following year, Mr. Phillips found the species abundant at Geneva, Ind., where the females of the summer form were just beginning to emerge from the young wheat; and the senior author observed it again at Charlotte, N. C., May 9, with indications that it had done considerable injury to young wheat. Mr. Phillips observed it during 1907 at Kingfisher, Okla., and at Beloit, Kans., on April 15; at Lenora, Kans., May 20; and at Kearney, Nebr., May 24. In all cases it was more or less abundant. June 1 of the same year Mr. C. N. Ainslie found adults of the spring form at Wellington, Kans.; from April 30 to May 7 he found the adult females of this form abroad in the fields at Sterling, Kans.; and on May 26 he found them ovipositing in wheat at Hays, Kans., and other points

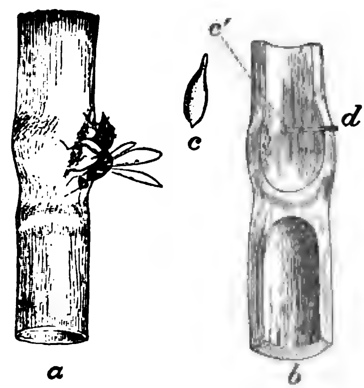


FIG. 8.—Method of oviposition of female of summer form of *Isosoma grande*: *a*, Female inserting her eggs; *b*, section of wheat stem showing egg and ovipositor; *c*, egg, greatly magnified; *c'*, egg in position in pith of wheat stem; *d*, ovipositor. (*a*, After Riley; *b*, original.)

farther west. He found them ovipositing in durum wheat at Oakley, Kans., June 3, and on the following day also in durum wheat at Colby, Kans. Again, June 8, he found them abroad in wheat fields at Manhattan, Kans. Females of the summer form were observed by Mr. E. O. G. Kelly ovipositing at Caldwell, Kans., May 14, 1908.

May 26 to 28, 1908, Mr. Ainslie found both sexes, the females ovipositing, near Chambersburg, Pa. This is the farthest east that we have any record of the existence of the species, the most eastern point of occurrence previously known being at Andover, in extreme northeastern Ohio, where the senior author found the larvæ in wheat straw, August, 1904.

As will be observed from the foregoing, the adult female emerges early in spring and deposits her eggs in the young wheat plants before the latter have made much growth. By the time wheat is beginning to show the heads within the enfolding sheath leaves, adults of the

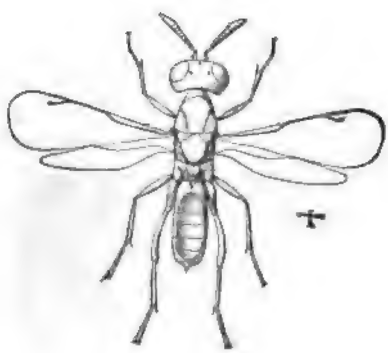

FIG. 9.—*Eupelmus allynii:* Male, much enlarged. (From Riley.)

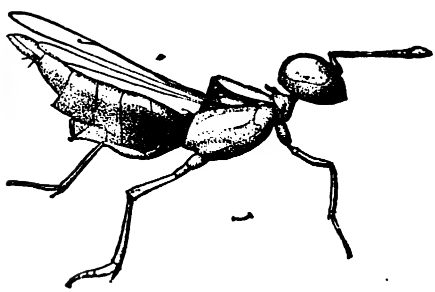

FIG. 10.—*Eupelmus allynii:* Female, much enlarged. (From Riley.)

second generation are abroad and depositing in the upper stems; the larvæ from these pass the winter as pupæ and emerge as adults early the following spring, exact dates of course varying with the latitude and other influences.

### NATURAL ENEMIES.

Probably the most efficient enemy of this species is a small, slender, four-winged fly (figs. 9, 10), with a somewhat brilliant metallic body and yellow legs. It has a very slight resemblance to an Isosoma, and, indeed, was described by French as *Isosoma allynii*, but it is now known as *Eupelmus allynii*. A somewhat similar insect with metallic body and yellow abdomen, *Semiotellus isosomatis* Riley (fig. 11), is very efficient in destroying the larvæ in the straw. *Homoporus* (*Semiotellus*) *chalcidiphagus* Walsh (fig. 12), and beyond a doubt other chalcidids, are also instrumental in holding it in check. These

parasites are all the more efficient as they are double-brooded, developing in late summer and at once ovipositing in other larvæ.

In 1908, at Wellington, Kans., Mr. E. O. G. Kelly, beginning April 10 with the larvæ in the straw, followed the insect up to June 4, witnessing oviposition in both the spring and summer forms. Through the remainder of June and most of July he was absent, and on his return he was unable to find the larvæ in the straw, although stubble and straws perforated with holes made by the escaping parasites were found everywhere in the fields. On account of the abundance of such evidence in the fields, Mr. Kelly was convinced that the pest had been largely overcome in that locality by *Eupelmus allynii.* At Pratt, Kans., November 17, a few larvæ were found in wheat straws, with indications that parasites had been present to a limited extent, and practically the same situation was found to occur at Sedgwick, Kans., the following day. Quite significant, however, was the fact that in the vicinity of Pratt, on September 16, Mr. T. D. Urbahns found in an

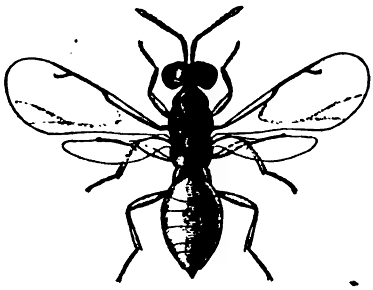

FIG. 11.—*Semiotellus isosomatis:* Parasite of *Isosoma grande.* Greatly enlarged. (Original.)

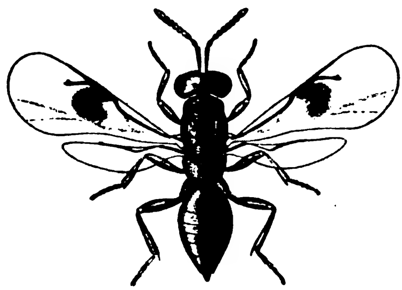

FIG. 12.—*Homoporus chalcidiphagus:* Parasite of *Isosoma grande.* Greatly enlarged. (Original.)

old wheat field not a single living Isosoma larva, while 85 per cent of the straws gave unmistakable evidence by the holes in them that these larvæ had been present, but were destroyed by parasites.

Quite in accord with this it will be remarked that the junior author, in his discussion of the outbreak of the pest in Washington State, in 1908, does not mention parasites at all—not because he overlooked the matter, but because he reared only a single individual parasite, probably *Semiotellus isosomatis* Riley, and there was no evidence of the presence of parasites in any numbers in the section of country visited by him. This will perhaps throw some light upon the prime causes of this outbreak. Besides, it opened the way for an introduction into Washington State of the parasites affecting the pest in the East. It is as yet too soon, however, to expect definite results from these introductions.

In Indiana and the Middle West when the wheat is harvested the straw is frequently, and, in fact, almost invariably, cut off between

joints, thus leaving the larvæ, if there are such in the straws at that point, exposed to attack from predaceous insects. The larvæ of a small, slender, black and yellow carabid beetle (*Leptotrachelus dorsalis* Fab.) crawls up the stalks, descends into the stubble, and devours the Isosoma larvæ, but unfortunately its taste is such that it does not confine itself strictly to Isosoma but devours parasite as well as host. The mite *Pediculoides* (*Heteropus*) *ventricosus* (fig. 13) is also an enemy, gaining access to the larvæ precisely as do the beetle larvæ previously mentioned.

## PREVENTIVE MEASURES.

There are no remedial measures, since it is impossible to alleviate or influence in any way the effect of larvæ in the infested wheat plants. As it is the larger and more vigorous plants that the females select for egg-laying purposes, no amount of enriching the soil will affect the numbers of the pest or lessen their influence. Preventive measures are, however, simple, practicable, and effective. Indeed, the wheat-straw worm is one of the very easiest of all insects to control. The diminutive size of the female that emerges in early spring renders extended migrations fatal, since during that period, when the weather is, of all seasons, the most erratic and liable to sudden and extreme changes, it tries to avoid the frequent storms by seeking protection on the underside of the leaves of the growing plants. But, most fortunate of all for the farmer, large numbers, if not indeed much the greater proportion, of these females have no wings and can only make their way from place to place by crawling.

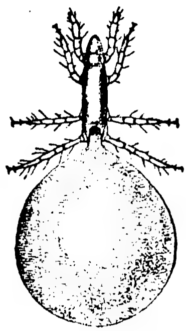

FIG. 13.—*Pediculoides ventricosus* Newp., a mite which destroys the larva. Much enlarged. (After Marlatt.)

The advantage of all of this to the farmer is shown by the fact that, where the preceding crop has been other than wheat, the injury to the young wheat plants in spring is confined to the margins, and especially where such margins border on other fields that have been devoted to wheat for a number of consecutive years. Mr. Reeves, as will be observed further on in this publication, has been able to measure the relative diminution of attack from the borders of the field inward toward the center. Similar observations had previously been made in other sections of the country. One of the earliest notes made on this species by the senior author was in June, 1884, in a field of wheat sown the previous autumn, among corn, the land bordering to the south on a stubble field. The following spring there were many wheat plants injured along the south margin of the field, but none could be found along the northern border. With the appearance of

the second generation, composed of large, vigorous females with well-developed wings, the diffusion would become comparatively general, and, therefore, the second year, if the field were to be continued in wheat, would find the infestation more nearly uniform throughout.

It is significant, too, that the pest becomes much more destructive the longer wheat is grown continuously on the same ground. As early as 1882 Prof. G. H. French observed that while 93 per cent of the straws were infested in a field where the same grain had been grown the year before, in a field where clover had been grown the previous year only about 5 per cent of the straws were infested. At Petty, Tex., April 14, 1905, the junior author found a field of wheat that had been in this grain for two consecutive years very seriously injured. There were spots several yards square where the ground was bare, and surrounding these were areas where half of the living plants were infested. At Sawyer, Kans., in an old field, Mr. Urbahns found that 85 per cent of the straws gave unmistakable evidence of having been infested. All of this points conclusively to the efficiency of a rotation of crops that will eliminate the growing of wheat two years in succession on the same land. Where for any reason this can not be done, the measure next in efficiency will be the burning of the stubble and outstanding straw during the fall or winter.

## RELATIONS OF THE WHEAT STRAWWORM TO WHEAT PRODUCTION IN THE NORTHWEST.

By Geo. I. Reeves.

The wheat strawworm, by reason of its relation to both the climate and the farm methods of the most productive portion of the Pacific Northwest, is capable of great injury to wheat growers. Though its greatest inroads are made upon spring wheat, it is winter and volunteer wheat which render those inroads possible. Its work is of such nature that it passes unobserved, unless an attack of unusual severity causes the farmer to scrutinize his fields more closely than he is accustomed to do. The constant small losses occasioned by this insect and the possible destruction of the crop over considerable areas may be prevented by such measures as every good farmer employs to maintain the fertility of his soil, secure a good seed bed, retain moisture, and eradicate weeds.

The strawworm may be found wherever wheat is grown in the Columbia basin, that great and fertile plain of varying topography and climate which is inclosed by the Okanagan Highlands on the north, the Rocky Mountains on the east, the Blue Mountains on the south, and the Cascade Mountains on the west; but it is not equally destructive over all that territory. The central and western parts of this basin, except in the Goldendale and Horse Heaven districts,

are arid, producing little or no wheat, and a strip east of this, known as the dry-farming region, where the scanty rainfall makes it necessary to summer-fallow the land every second year, is by that means protected from serious injury; but the eastern zone, a strip 200 miles long, included between the dry-farming area and the upper limit of wheat culture at the elevation of 3,000 feet, affords ideal conditions for the production of small grains and also for the propagation of this insect. The climate is characterized by mild winters suitable for the growing of winter wheat—cold, wet spring weather, such as is desirable for all small grains, and hot, dry summers perfectly adapted to the maturing and harvesting of the crop. The soil is such that after more than thirty years of almost continuous production it still yields 30 to 40 bushels of wheat per acre. These conditions encourage the seeding of wheat year after year upon the same ground, and such a practice, together with the presence of winter or late volunteer wheat, supplies the requirements for the unhindered multiplication of the strawworm. Owing to the drought of summer the volunteer wheat usually does not germinate until about the same time as the fall-sown wheat, and the significance of this fact appears when we come to study the insect's life history.

This Isosoma passes the winter in the larval (fig. 1) or pupal (fig. 7) stage and reaches maturity early in April. It gnaws its way out of the stubble in which it has hibernated and deposits its eggs in the heart of the young plants of winter or volunteer wheat (fig. 6), which must be near the place of emergence, since this early generation is largely wingless (fig. 3), and its effective range as measured by the spread into an adjoining field is not much more than 12 feet. The food plants of the early generation may be supplied by winter wheat or by volunteer wheat not too far advanced to attract the insect. The oviposition is finished before any spring wheat is up, so that that crop suffers no attack from the first generation. The winter and volunteer wheats lend an essential aid to the perpetuation of the species.

The larva (fig. 5), when it hatches from the egg, is surrounded by the most delicate tissues of the plant and feeds upon them, destroying the young head and thus excavating a residence to accommodate its rapidly increasing size. The outer, tougher layers, which it does not attack, gradually become fleshy, stiff, and brittle, forming a hollow, bulblike swelling at the base of the plant. This enlargement is discernible from the outside of the infested plant, and its presence may be verified by squeezing the crown of the plant between the fingers, whereupon the bulb at first firmly resists pressure and then breaks open, disclosing the larva. The infested plant suffers a change in external form, which causes it to resemble wheat

injured by the Hessian fly and by Meromyza, but it may usually be distinguished from the former by the curly and slightly fleshy form of the blades; from the latter by the absence of the brown, threadlike central shoot, as well as the form of the blades; and from both by the presence of the crisp bulb at the crown. The lower blades are broad, dark bluish green, curly, and slightly fleshy, because they arise between the root and the point of injury and thus receive the sap that is being diverted by the larva from the main growing point of the plant. The plant, when attacked thus early at the heart, remains low, does not produce any head, and perishes when the lower blades of the plants naturally die, about the middle of June. At about the same time the adults of the second generation (fig. 4) begin to emerge from these plants and deposit eggs upon the wheat. These insects, as were those of the first generation, are nearly all females, and they also reproduce without the assistance of males, but they differ from the earlier form in being larger and in possessing wings, which enable them to attack fields at a distance from their origin. They prefer the younger plants, and as the spring wheat is small at this time, while the winter wheat is old and tough, the summer attack is concentrated upon spring wheat, if there be any in the vicinity. They attack it in much the same way that the spring generation employs upon the young winter wheat, and with the same result; the smaller plants simulate a luxuriant growth, but remain short and soon die; the larger ones may produce heads, a few inches above ground, but such heads contain no kernels. Thirty acres of spring wheat near Colfax, Wash., were completely ruined in this manner in the summer of 1907.

Since spring wheat is not so extensively grown as formerly in this region, the summer adults are often compelled to oviposit in winter wheat, and in those cases the plant is less severely injured, because it is old and tough; but the larva of the insect and the resulting adult take the same form and size whether they develop in the tender spring wheat or in the more mature winter wheat. The succulence of the former does not cause an increase in the size of the larvæ which feed upon it, nor does it produce a larger proportion of winged individuals among the adults. On the contrary, it seems that austere and unfavorable circumstances tend to increase the number of winged adults, as a large percentage of those reared from stubble collected at Goldendale, St. Germain, and Waterville, Wash., in the arid district, have wings. The egg is placed in a tender joint near the head (fig. 8) and the larva hatches and gnaws the inner surface of the stalk, too late to prevent the formation of the head, but early enough to shorten it and hinder the filling of the kernels. To ascertain the amount of this injury 1,452 heads taken from an apparently unin-

jured field of winter wheat near Pullman, Wash., were dried and weighed. Thirty-nine per cent of these were afterwards found to have grown upon stems damaged by the strawworm, and the average weight of the heads from these damaged stems was 22 per cent below the average of healthy heads, although no difference in size was noticeable until the heads were placed side by side, when it was found that most of the larger heads were those from uninjured plants, while most of the shorter ones were from infested plants. Between heads of the same size there was a difference of 7 per cent, which could not be detected except by weighing.

Both the work of the spring brood in fall wheat and that of the summer brood in spring and winter wheat are so carried on that the owner does not know of his loss unless it amounts to a very large percentage of the crop, and even then he may attribute it to some other cause. The presence of a large number of unusually rank and apparently sturdy plants among the winter wheat does not seem alarming, but the reverse; and there is no other indication of work of the spring brood. Later, when these infested plants begin to die they are concealed by the yellowing blades of the healthy plants, so that even the trained entomologist can hardly find them. The same is true of the spring wheat which is attacked by the summer brood, while winter wheat plants attacked by the summer brood are, as we have just shown, so little altered in appearance that the presence of the insect can be detected only by weighing the heads or splitting the stems to look within for the larvæ.

Many of the larvæ remain in the stubble if the grain is cut with a harvester, and most of them if it is cut with a header. They begin to pupate during the latter half of July, but many remain in the larval condition until May of the following year.

The life history just related shows that strawworm injury is induced by growing crops of winter wheat repeatedly upon the same ground; by leaving volunteer plants among the spring wheat; by allowing summer fallow to grow foul with volunteer wheat, even at a distance from wheat fields; and by growing spring wheat near winter wheat. All of these cases occur at times in the wheat country which we are considering. The essential conditions in each of these cases are, first, the presence of infested stubble, plowed or unplowed, to furnish the early adults; second, a growth of winter or volunteer wheat early in the spring to receive the eggs of the first generation; third, a crop of winter or, preferably, spring wheat to receive the eggs of the second brood. The remedy lies in avoiding these conditions by rotation of crops, clean early summer fallowing, and the abandonment of spring-wheat culture. Fall plowing of the stubble does not prevent the insects from coming out and attacking wheat in the

spring. Burning the stubble is impracticable, because the joints which contain the larvæ remain sappy during the fall and will not burn. Rotation, to be effective, must bo planned with reference to the work of the insect, since two adjoining fields which are in wheat in alternate years have between them a strip 2 rods wide which always furnishes ideal conditions for its spread. The stubble in one field always furnishes insects to attack the growing wheat in the other, and while the damage done by the wingless first generation is limited to the 1-rod strip next the fence, the winged second generation spreads at will through the field.

There is no reason why an insect, so readily held in check merely by careful farm methods, should cause constant loss and an occasional menace to the wheat country of the Northwest, but there is no doubt that it does so.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *April 10, 1909.*

[Cir. 106]

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CIRCULAR NO. 107. Issued January 12, 1909.

United States Department of Agriculture,
BUREAU OF ENTOMOLOGY,
L. O. HOWARD, Entomologist and Chief of Bureau.

# WHAT CAN BE DONE IN DESTROYING THE COTTON BOLL WEEVIL DURING THE WINTER.

By W. D. HUNTER,
*In Charge of Southern Field Crop Insect and Tick Investigations.*

## IMPORTANCE OF WINTER WORK.

The boll weevil attracts greatest attention during the growing season of cotton, for the simple reason that its damage is then most evident. When the infested squares are falling by millions every day the planter is driven to most strenuous efforts to check the loss. The summer season, however, is the one in which it is most difficult to combat the weevil. The pest can be attacked in various ways at different seasons of the year. This circular attempts to point out what can be done in the winter when the weevils are in hibernating quarters and when natural conditions are assisting the farmer greatly by reducing the number that will be able to survive until spring. At this time the farmer can undoubtedly accomplish more than by hand-picking weevils and squares or any other direct method of control that can be put into operation in the summer season. A great advantage that winter work has in many cases is that it involves no special outlay and consequently adds nothing to the cost of producing cotton. The work can be done during the quiet period of the winter and at such times as will not interfere with the general work of the plantation. Even on plantations run largely or entirely by "wages hands" this work would undoubtedly warrant an outlay on the part of the planter. As a matter of fact the winter season could well be made the most active of the year as far as the destruction of the weevil is concerned.

It is true that the Texas farmers have not paid much attention to work against the weevil in the winter, but this does not by any means indicate that such work will not be of prime importance to the planters in Louisiana and Mississippi. Nature has afforded the Texas farmer many advantages over the planter in the eastern part of the cotton belt. As has been pointed out in other publications of the Bureau of Entomology, the Mississippi Valley planter will be compelled to contend against many more weevils each spring than the climatic conditions in Texas have ever permitted to survive. For instance, in the spring of 1908 it was determined by Mr. Wilmon Newell, secretary of the State crop pest commission of Louisiana, that as many as 6,000 hibernated weevils per acre made their appearance in certain cotton fields in Avoyelles Parish, Louisiana. This shows a survival of weevils far beyond what has ever been found in Texas. There are many other indications of the special seriousness of the weevil problem in the Mississippi Val-

ley. All this demonstrates that the planters in regions recently invaded by the weevil must resort to every means of control that is known and must utilize to the fullest extent such methods as the Texas farmers may not have been compelled to practice.

The all-important step in the control of the weevil is the destruction of millions of individuals and the prevention of the development of many more by uprooting and burning the cotton plants in the fall. This is a step that indications show clearly is going to be indispensable in the Mississippi Valley. In the light of what is now known it would be folly for planters to attempt to produce cotton unless they follow this practice religiously. If, for any reason, the cotton plants have not been removed in the fall, some good can be accomplished by their removal later in the season. The proper thing to be done by the planter who desires to reduce weevil damage to the minimum is to combine the fall destruction of the plants with such measures, to be taken later in the season, as are outlined in this circular. *The advice now given is not to depend upon winter work altogether for the control of the weevil. The winter work is merely a second step, to be taken in connection with the destruction of the weevils and the prevention of the maturity of the fall broods by uprooting and burning the plants. Where that step has not been taken, the work outlined in this circular is the main dependence of the planters at this time.*

## WHERE WEEVILS ARE TO BE FOUND DURING THE WINTER.

The whole question of what can be done to destroy the weevils in the winter depends upon where they are to be found. The Bureau of Entomology has taken pains to determine the localities in which the weevils secrete themselves during the winter months. Some weevils fly outside of the cotton fields into the timber before frost has killed the cotton. Of course, such individuals as fly great distances from the cotton fields, or into heavy timber, are entirely beyond the reach of the planter. The remainder of the weevils, however—those remaining in and about the cotton fields—are more or less at the mercy of the planter for several months during the winter.

In cotton fields and in their immediate vicinity weevils have been found hibernating in four principal situations: *First*, in burrs and unopened bolls on the plants; *second*, in bolls or portions of bolls that have been knocked to the ground; *third*, under such trash as leaves and grass abounding in most cotton fields; *fourth*, in the cracks in the ground caused by drying.

The numbers of weevils found in the situations just mentioned show clearly what opportunities the farmer has for their destruction. On January 16, 1907, a field near Wolfe City, Tex., showed from 363 to 1,500 live weevils per acre in the burrs still hanging to the plants. These were generally in the partly opened locks where weevils had matured in the fall, but some were in locks from which all of the cotton had been removed. On January 27, 1907, as many as 2,250 weevils per acre were found on the ground in a cotton field near Dallas, Tex. The number was determined by raking all of the trash carefully from a square rod of ground and examining it in the laboratory. On December 18 living weevils at the rate of 1,056 per acre were found at Dallas. On January 16 320 living weevils per acre were found in burrs and under leaves and grass in a cotton field at Victoria, Tex. On Novem-

ber 15 4 weevils were found in the cracks around the bases of 22 cotton plants growing near Dallas. This indicates a total number of weevils per acre in such situations in this field of 1,090.

Practically all of the weevils to be found in the situations described can be killed by raking and burning the trash, except those in cracks in the ground, and these, in the majority of cases, would probably be crushed by winter plowing of the fields.

## PLOWING NOT EFFECTIVE.

The point may be raised that winter plowing, by burying the weevils found in trash on the surface, might have the same effect as burning. On the contrary, experiments have shown that weevils can easily make their way through several inches of soil. Consequently such work in general is as likely to protect as to destroy the weevils. Of course, if heavy rains should follow immediately after plowing, it is possible that some soils would be so compacted as to prevent the emergence of weevils. Nevertheless, this could not happen under usual conditions. In the case of weevils in cracks, destruction would not result from burial but from crushing.

What has just been stated should not be taken to mean that winter plowing should not be followed. As a matter of fact, the winter working of the fields should be practiced, not only on general principles, but to assist in procuring an early crop. The present purpose is merely to point out how to destroy the boll weevil in the winter. Regardless of its other benefits, winter plowing can not be depended upon to actually kill many weevils.

## WEEVILS THAT CAN BE REACHED OUTSIDE OF COTTON FIELDS.

In addition to those in the cotton fields themselves, many weevils can be reached that have found winter quarters along turn-rows, in ditches, along fences, and in the trash that is frequently allowed to accumulate around seed houses. Fire is again the agent of destruction at the command of the farmer. Careful burning of turn-rows and ditches and cleaning of fence corners and similar situations will result in the death of many weevils that might survive to damage the crop of the following season.

The work of burning and cleaning the plantation should not stop with the immediate vicinity of cotton fields. Many weevils fly into corn fields, where they find suitable quarters for passing the winter. These fields, on a cotton plantation, should be cleaned during the winter as thoroughly as the fields where cotton has been growing or is to be grown during the next season. It has been found that sorghum fields furnish exceptionally favorable opportunities for hibernating weevils. The heavy stubble left by this crop catches grass and general débris blown about by the wind, which then becomes heavily matted. Here many weevils are to be found during the winter. In many cases in Texas the earliest appearing weevils and the greatest damage to the crop have been shown to be chargeable to neighboring sorghum fields which have served as winter quarters for the pest.

Many weevils undoubtedly find hibernating quarters in trash along railroad rights of way as well as along wagon roads. The importance of such means furnished the weevil for passing the winter becomes great where, as in many cases, the roads or railroads pass through localities

where cotton fields adjoin the public property. It should be the duty of railroad and county authorities in such cases to assist the farmers as far as practicable by removing the shelter for the weevil.

### WEEVILS IN COTTON SEED.

Cotton seed has frequently been supposed to furnish exceptionally favorable winter quarters for the weevil. It has been shown that many weevils pass through the gins and are later to be found in the bulk cotton seed in storage. Up to a certain time in the winter cotton seed is very likely to contain live weevils. Many experiments, however, have shown that very few are able to survive in this medium until spring. This seems to be due principally to the absence of moisture. Repeatedly numbers of weevils have been placed in cotton seed in the fall. Altogether 6,600 weevils have been used in these experiments. They were placed under a variety of conditions. Although many have survived until the middle of winter, only two lived until the first of April. It is therefore clear that cotton seed itself is not an especially dangerous commodity. Although it is true that the earliest weevils frequently make their appearance in the vicinity of seed houses, this is to be accounted for by the fact that the insects find quarters under the building and under the trash that is allowed to accumulate in such situations rather than in the cotton seed itself.

### CONCLUSION.

The climatic and labor conditions surrounding cotton production in Louisiana and Mississippi leave no doubt that the planters in those States must not overlook any important means of controlling the boll weevil. *This circular points out one important and inexpensive means that can be practiced by every planter.* It is of special importance in the humid regions recently invaded where fears of disaster are now commonly entertained. The Department of Agriculture urges that cotton raisers take advantage of the enemy while they have the opportunity and by the means herein described greatly increase the chances for producing a crop the coming season.

Approved:
JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *December 19, 1908.*

A6—31

CIRCULAR No. 108.

Issued February 11, 1909.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# HOUSE FLEAS.

By L. O. HOWARD.

Judging from the specimens of fleas sent to the Bureau of Entomology of recent years with complaints of houses being infested by them, the human flea (*Pulex irritans* L.) is not the species most likely

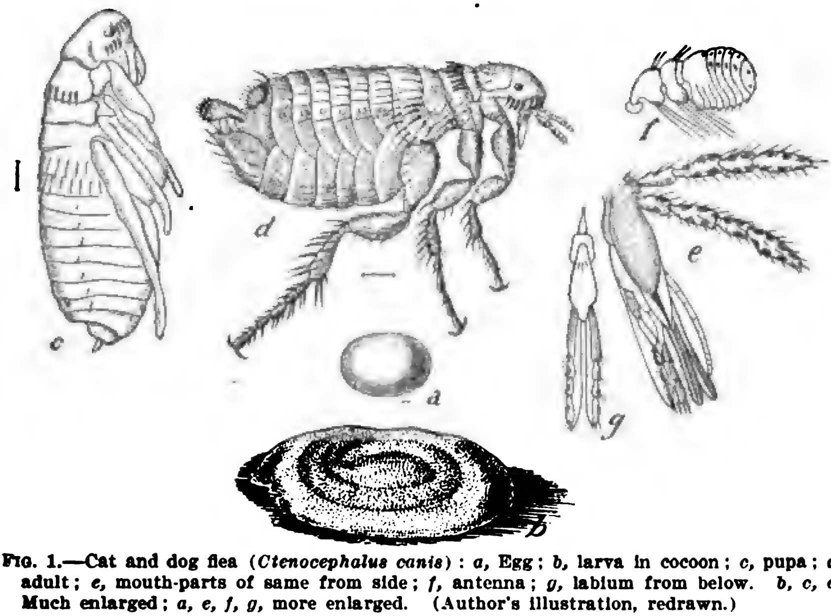


FIG. 1.—Cat and dog flea (*Ctenocephalus canis*) : *a*, Egg ; *b*, larva in cocoon ; *c*, pupa ; *d*, adult ; *e*, mouth-parts of same from side ; *f*, antenna ; *g*, labium from below. *b, c, d*, Much enlarged ; *a, e, f, g*, more enlarged. (Author's illustration, redrawn.)

to occur in great numbers in dwelling houses in this country, but rather the common, cosmopolitan flea of the dog and cat (*Ctenocephalus canis* Curtis).[a] This holds especially for the eastern

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[a] In the earlier publications of this office, Bulletin 4 and Circular 13, this species has been referred to under the name *Pulex serraticeps* Gerv.

United States. *Pulex irritans* is sometimes found in houses in California, and is the prevailing household flea of Europe. A house may become infested with the cat and dog flea even though no domestic animals be kept, for a visitor at a house where such pets are maintained may be the means of carrying home with him one or two female fleas which will stock his own premises. Of course, where a pet dog or cat is kept, the source of the infestation is manifest.

The worst cases of infestation reported to this Bureau have usually been those in which houses had been temporarily unoccupied during the summer. Such houses during a rainy summer become more or less damp, and as a rule the customary sweeping of the floors is interrupted, thus furnishing the very conditions under which, as we shall see, fleas most readily propagate.

The eggs (fig. 1, *a*) of *Ctenocephalus canis* are deposited among the hairs of cats and dogs, but as they are not attached to the hairs, numbers drop off whenever the infested animal moves or lies down. From these eggs hatch the larvæ (fig. 2, *a*), which are slender, minute, white, wormlike creatures. They are very active, crawl rapidly, penetrate into the cracks of the floor, and live there until full grown, feeding upon such organic matter as may have collected in the cracks. They develop rapidly, and in midsummer in Washington reach full growth in a short time. On reaching full growth the larva spins a delicate, white, silken cocoon (fig. 1, *b*), and transforms to pupa (fig. 1, *c*), the adults (fig. 1, *d*) issuing a few days later. A whole generation may develop in the course of a fortnight in warm, damp weather, but a great excess of moisture results in the destruction of the larvæ. With this rapid development under the most favorable conditions, a housekeeper, shutting up her house in June, for example, with a colony of fleas too small to be noticed inside the house, should not be surprised to find the establishment overrun with fleas when she opens it again in September or October.

## REMEDIES.

If you do not desire to be troubled by fleas, do not keep cats or dogs. If you must keep a pet dog or cat, provide a rug for the animal to sleep on, and give this rug a frequent shaking and brushing, afterwards sweeping up and burning the dust thus removed. As all the flea eggs on an infested animal will not, however, drop off in this way, and as those which remain on it will probably develop successfully, it will be found wise to occasionally rub into the hair of the dog or cat a quantity of pyrethrum powder. If thoroughly applied, this powder will cause the fleas to fall off in a half stupefied condition, when they, too, may be swept up and burned.

The larvæ of the dog and cat flea will not develop successfully in situations where they are likely to be disturbed. The use of carpets

and straw mattings, in the writer's opinion, favors their development, since the young larvæ can penetrate the interstices of either sort of floor-covering and find an abiding place in some crack where they are not likely to be disturbed. It is comparatively easy to destroy the insect in its early stages (when it is noticed), but the adult fleas are so active and so hardy that they successfully resist any but the most strenuous measures. Even the persistent use of California buhach and other pyrethrum powders was ineffectual in one case of extreme infestation, as was also, and more remarkably, a free sprinkling of floor mattings with benzine. In this instance it was finally necessary to take up the floor-coverings and wash the floors down with hot soapsuds in order to secure relief from the flea plague. In another case, however, a single liberal application of buhach was perfectly successful, while in a third a single thorough application of benzine completely rid an infested house of fleas.

In bad cases almost nothing will avail without the greatest care in keeping the floor and other coverings, as well as crevices, etc., free from dust and dirt. The old remedy often mentioned of putting a piece of raw meat upon a sheet of sticky fly paper, in the hope that the fleas will jump for the meat and be caught by the fly paper, has been thoroughly tried by the writer without success. Where there are comparatively few fleas in a house or in a given room, the following somewhat laborious plan will result in eradication. Place a white cloth, like a pillowcase, in the middle of the floor. The fleas, attracted by the white color, will jump on the cloth. Then, with a basin of water, kneel down and with the wetted forefinger pick up the fleas one after another and put them in the water. The writer has known several houses in Washington to be rid of rather sparse populations of fleas in this manner.

Mr. E. M. Ehrhorn, of San Francisco, gives the following remedy, which he states he has tested and which his mother used with effect in South America. Fill a glass three-fourths with water, on top of which pour about an inch of olive oil, then place a night float (a little wick inserted in a cardboard disk or in a cork disk) in the center of the oil. Place the tumbler in the center of a soup plate filled with strong soapsuds. The wick should be lighted at night on retiring, or may be used in any dark room. As the soup-plate-soapsuds trap is placed on the floor of the room it does not interfere with the sleeper, and the fleas which are on the floor are attracted to the light. For outbuildings, such as barns, etc., a large milk pan may be used, and instead of using olive oil and a glass, a stable lantern may be placed in the center of the pan, while instead of soapsuds a scum of kerosene may be put on the water in the milk pan.

To sum up: Every house where a pet dog or cat is kept may become seriously infested with fleas if the proper conditions of moisture and freedom from disturbance exist. Infestation, however, is not likely to occur if the (bare) floors can be frequently and thoroughly swept. When an outbreak of fleas comes, however, the easiest remedy to apply is a free sprinkling of pyrethrum powder in the infested rooms. This failing, benzine may be tried, a thorough spraying of carpets and floors being undertaken, with the exercise of due precaution in seeing that no lights or fires are in the house at the time of the application, or for some hours afterwards. Finally, if the plague is not thus abated, all floor coverings must be removed and the floors washed with hot soapsuds. This is a useful precaution in any house which it is proposed to close for the summer, since even a thorough sweeping may leave behind some few flea eggs from which an all-pervading swarm may develop before the house is reopened.

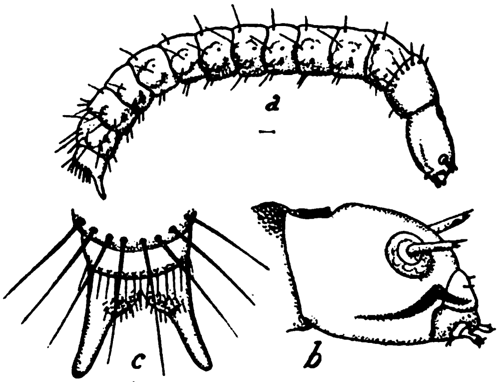

FIG. 2.—Cat and dog flea (*Ctenocephalus canis*): *a*, Larva; *b*, head of same; *c*, anal end of same. *a*, Much enlarged; *b*, *c*, more enlarged. (Author's illustration, redrawn.)

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *December 29, 1908.*

[Cir. 108]

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CIRCULAR No. 109. Issued July 6, 1909.

# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE LEOPARD MOTH.

(*Zeuzera pyrina* Fab.)[a]

By L. O. HOWARD and F. H. CHITTENDEN.

### INTRODUCTORY.

Deciduous trees of many kinds, grown for shade and for ornament in northern New Jersey and eastern New York, are subject to severe injury by the larval stage of the European leopard moth (*Zeuzera pyrina* Fab.). Among the shade trees, elms and maples suffer the greatest damage, but as this species is a very general feeder it attacks practically all descriptions of trees and shrubs with the exception of the evergreens. In the region mentioned this species is, everything considered, the most serious menace to the growth of shade trees, since, unlike the majority of lepidopterous insects, the larvæ of the leopard moth do not feed upon the foliage, but bore into the branches of the plants which they infest and feed upon the living wood. The larvæ usually begin operations in twigs and small branches and with their larger growth bore and tunnel into the larger branches and trunks. This work has the effect of girdling, the injured portions being blown down by heavy wind storms, while in the case of severe attack the growth of the tree is checked, frequently causing its death. Attack is not confined solely to shade and ornamental plants, but orchards are often injured.

### DESCRIPTIVE.

Injury by this species is accomplished solely by the larva, which is a fleshy, grublike caterpillar, pale yellowish in color, frequently with a pinkish tinge. The head, thorax, and anal plates are brownish-black and the surface of the body is very sparsely hairy but covered

[a] Family Cossidæ. Synonyms: *Zeuzera æsculi* L., *Z. decipiens* Kby., etc.

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with large and prominent tubercles arranged as shown in the illustration (fig. 1, *c*). When fully mature the larva attains a total length of about 2 inches. A lateral view of the larva in its burrow is shown in figure 1 at *c*.

This species derives its name from the spotted appearance of the moth, illustrated at figure 1, *a*, *b*. There is great diversity in the size of the two sexes, the female (*a*), which is a heavy-bodied moth and a very feeble flyer, being much the larger. It will be noticed that the smaller male (*b*) has a more slender body, which permits a more ready flight, and is also distinguished from the female by the pos-

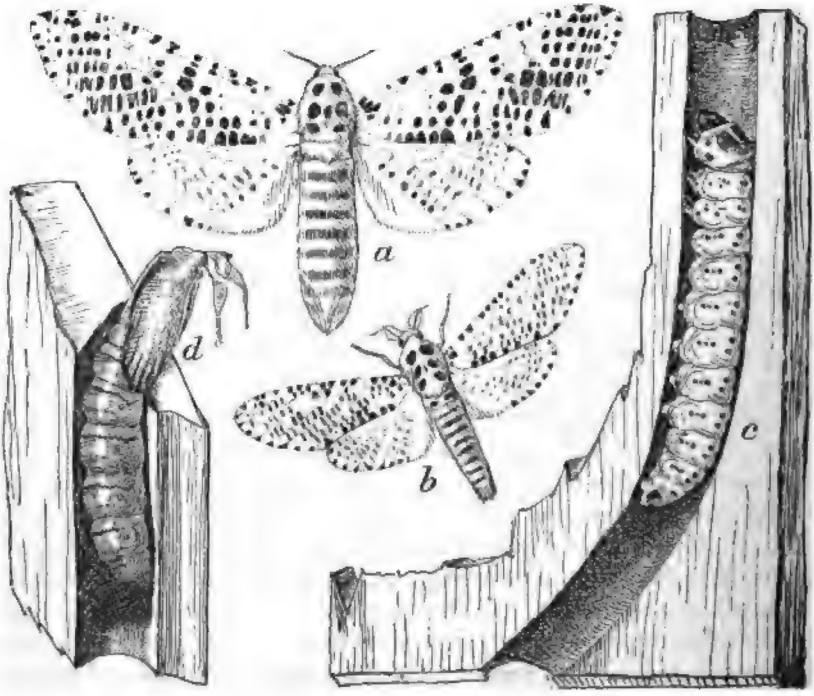


**Fig. 1.—The leopard moth (*Zeuzera pyrina*): *a*, Adult female; *b*, adult male; *c*, larva; *d*, empty pupal case. Enlarged. (Original.)**

session of broad bipectinate or feathery antennæ. The wings are semitransparent and white, thickly dotted with blackish spots which are more or less distinctly tinged, giving them a dark blue or greenish cast. The thorax is marked with six large black spots and one small one, the latter being located in the center. The female has a wing expanse of upwards of one and a half inches, while that of the male is much less.

An empty pupa-case in its cell in the wood is shown in the illustration at *d*.

## ORIGINAL HOME AND DISTRIBUTION.

The leopard moth, like so many other dangerous pests, is a European species which has been introduced into the United States in comparatively recent years. Its old world distribution is credited as central and southern Europe, southern Sweden, southwestern Africa, Algeria, and northern Morocco, and the western portion of Asia Minor.

This species was introduced into the United States some time prior to 1879, in which year, on the authority of Mr. Jacob Doll, a living moth was captured in a spider's web at Hoboken, N. J.[a] In 1884 Dr. E. B. Southwick, then entomologist of the public parks of New York City, recognized the destructive work of this species in Central Park.[b] In 1887 it was seen at Newark, N. J., but was not actually recorded as occurring in this country until the following year. In 1890 the junior author observed the moths at electric lights at Orange, N. J.

Fortunately the spread of this insect, particularly in the immediate vicinity of New York City, has been very slow, a fact which may be attributed to several causes, (1) the slowness of the flight of the female, (2) the dominance of sparrows in large cities, causing our native birds, such as woodpeckers, to be driven to the country, where they destroy the moths, and (3) the bowl-shaped electric-light globes, hollow at the top and closed at the bottom, which were formerly in general use in our large cities. The males are strongly attracted to brilliant lights and many were captured and perished in these globes in earlier years. Other cities in New Jersey where this species has been troublesome are Elizabeth, Irvington, Montclair, Arlington, Asbury Park, Ocean Grove, and New Brunswick. Mr. H. M. Russell of this Bureau collected specimens at Bridgeport, Conn., in 1901. The species is now an inhabitant also of Staten Island and has spread on Long Island well beyond the confines of greater New York. Southward it was reported a pest, in 1901, at Ocean Grove, N. J., and by 1905 it was recorded by Felt as occurring at Kensico, N. Y., 25 miles north of New York City. By 1907 it was captured at New Haven, Conn., by Prof. H. W. Foote. It is now stated to be injurious in the vicinity of Boston, Mass.

## FOOD PLANTS.

In its original home the leopard moth is recorded as living on a considerable number of common trees, including elm, lime or linden, ash, beech, birch, walnut, oak, chestnut, poplar, alder, and, rarely, horse-chestnut. Among orchard trees it is reported to do injury to pear, apple, and plum. In the United States it attacks all of these

[a] Entomological News, March, 1904, p. 110. [b] Insect Life, Vol. VII, p. 138.

trees and many others, the list including such important shade trees as have been mentioned, as also practically all of the maples, elms, and oaks, mountain ash, tulip tree (*Liriodendron tulipifera*), aspen, the willows, and such shrubs as privet, lilac, and honeysuckle. A list of trees which this species has been actually observed to attack was compiled in 1894 by Doctor Southwick and includes 77, observed in the public parks of New York City alone. A total list of 83 trees and shrubs was made at that time.[a]

It will be seen by the list of food plants already presented that the number could be almost indefinitely extended, particularly in reservations like Central Park, New York City, and Prospect Park, in Brooklyn, where special effort has been made to bring together a great variety of trees and shrubs. The insect is, in fact, nearly omnivorous, attacking, as previously stated, practically all forms of woody plants which are of suitable size for its purpose, with the exception of conifers.

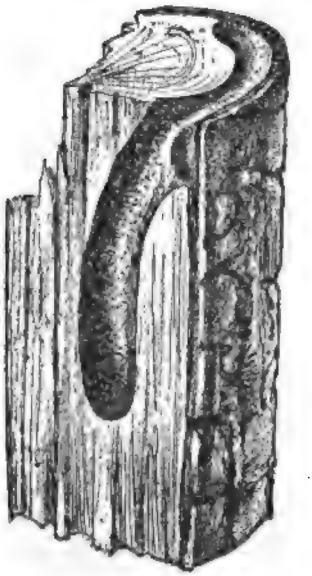

FIG. 2.—Section of wood showing burrow and girdling effect produced by larva of leopard moth. Reduced. (From Insect Life.)

HABITS AND LIFE HISTORY.

In Germany the moths are stated to make their appearance during July and August, while in this country they appear as early as May and continue issuing until late in September.

The gravid female, being particularly heavy, is unable to fly very far or very high. She deposits her oval, salmon-colored eggs in a large mass or group, when not in confinement, and as many as 300 eggs have been counted in a single mass. This is, however, probably not the maximum number, since an estimate of as many as 1,000 has been made. The eggs are introduced by the rather hard ovipositor into the soft tissue of young growth where the bark is smooth, or are inserted into crevices in the rough bark of older trees.

The larvæ soon hatch—in about ten days, according to Mr. J. V. D. Walker—and penetrate the wood, frequently entering the nearest crotch but boring in at other points, and burrow tunnels into the heart or pith of twigs and the heartwood of the larger branches or trunks. When a larva has grown too large for the branch in which it is feeding it crawls out and migrates to a larger one. In a single

[a] See list on page 529, Rep. Ent. N. J. Agr. Exp. Sta. for 1894. This article, by Dr. J. B. Smith, covers pages 517–533 and presents a very complete account of the insect.

tree 6 inches in diameter Southwick observed as many as six larvæ, any one of which would have been able to destroy the tree if not removed. Mr. A. Hufnal wrote that in maple trees which this species was infesting at Ocean Grove, N. J., there was an average of from six to eight borers to a tree and that he had found from ten to fifteen, and in one instance as high as thirty-four, in a single tree. By the time the larvæ within have attained full growth infested limbs of a certain size are likely to break off, especially during or after a severe storm, for the full-grown larva in many cases girdles the branch. The manner of girdling is shown at the top of the section of wood illustrated in figure 2. In 1893, after every storm in Central Park great quantities of limbs were seen, some entirely broken off and others still hanging to the trees.

The larva, when fully mature, transforms to pupa within the burrow, the change beginning to occur during the second May after the hatching of the eggs, the larva thus requiring nearly two years to complete its growth. The pupa, by means of a sharp protuberance on its head, is enabled to force its way partly out of the burrow, after which the skin splits open and the moth emerges. The empty pupal skin remains for some time projecting from the orifice.

The presence of this borer in a branch is manifested by little accumulations of chips, matted excrement, or frass, which indicate the entrance to the burrows. After a time these orifices are closed from within by a silken web, which is doubtless to protect the contained insect from its natural enemies. Smaller twigs wilt and break off and often it is only when the severed twigs or branches have been brought down in numbers by high winds that the work of the insect is first recognized. Where the larger larvæ have worked just under the bark this splits open the next season, leaving an ugly scar as a reminder of its pernicious operations.

## NATURAL CHECKS.

No specific natural enemies of the leopard moth appear to have been recorded in this country, although in Europe E. A. Fitch has reared an indeterminate chalcidid of the subfamily Encyrtinæ.[a]

In the explanation of the cause of the slow spread of the moth from cities and large towns to the country, allusion has been made to the fact that native birds probably assist in holding this insect in check in the suburbs. Actual observations on this head appear to be wanting, but there are the best of reasons for believing that birds, like the woodpeckers, which naturally look over the bark and collect all kinds of borers, prey on this species, while it is believed

[a] Entom. Mo. Mag., Vol. XVIII, p. 116. Perhaps *Copidosoma truncatellum* Dalm., mentioned by Dalla Torre (not Mayr), Catalogus Hymenopterorum, p. 246.

that sparrows sometimes destroy the eggs or young larvæ in such places. Smith has expressed the belief that when the insect succeeds in getting away from the outskirts of cities its enemies increase in number, many insectivorous birds aiding in holding it down.

During the day the moths must be fed upon by birds and later by bats and night-flying birds. The habit of the larvæ of deserting one twig and migrating to a larger one undoubtedly leaves them exposed to the same natural enemies, as this has been observed to happen in the daytime as well as after nightfall. It follows that the protection of native birds, especially the woodpeckers and related species, will greatly assist in restraining the undue increase of this borer.

### METHODS OF CONTROL.

The protected and concealed manner of life of this species, as shown by the life history, which will apply in the main to other borers also, renders it very difficult of treatment by means of insecticides or other direct measures. The most efficacious remedial measure consists in cutting off and destroying affected branches and in the injection of bisulphid of carbon into the holes or burrows where the larvæ are at work.

*Pruning and cutting back.*—Twigs or branches which, by their wilting or by the frass which accumulates at the entrance to their burrows, indicate the presence of this borer, should be carefully searched out, the smaller ones pruned away and the larger ones cut back, the amputated portions being promptly burned. After windstorms, the affected branches which have fallen to the ground and those which remain attached to the tree should be collected and burned. Wherever trees show that they are past recovery it is best to take them out and promptly destroy them. The word promptly is used advisedly, for this insect, as has been shown previously, frequently migrates from one twig or branch to another.

*Bisulphid of carbon.*—In the case of young and rare trees and others which show only a few larval burrows in the bark, bisulphid of carbon is the best remedy and one which has been in general use against the present species in the public parks of New York City. It is injected into the openings of the burrows, and the openings are afterwards closed with various substances. For this injection a mechanic's long-spouted oil can of small size may be used on large trees, but against a related species the writers have made very good use of a small glass syringe, such as may be purchased at any drug store for ten cents. These glass syringes are most serviceable, because the exact amount of bisulphid may be seen when drawn into the syringe and because the reagent does not injure the thread pack-

ing.[a] Metal syringes may also be used, but it is more difficult to measure the exact amount and the bisulphid acts on the leather packing. Rubber syringes can not be used because of rapid corrosion. About a teaspoonful of the liquid bisulphid is sufficient for each burrow.

For stopping the holes after injecting the liquid, putty and moist clay, advised by some, have not been found so serviceable as grafting wax. Coal tar may be substituted for the latter, or the holes may be closed by inserting a wooden plug and breaking or sawing it off level with the trunk. In any case the stopper should be tight, to exclude water from rains, which might tend to produce decomposition of the surrounding wood or invite other insects, like black ants and secondary borers, of which there are many species, and injurious fungi.

Carbon bisulphid should be handled with the usual precautions against fire, which means that the operator should not smoke while at work. Although a deadly poison, it will not injure ordinary trees when applied as described.

*Killing with wires.*—It is possible to reach and destroy some larvæ by forcing a copper or other pliable wire into the channels. This is a well-known borer remedy. It is impossible, however, by this means to kill the insects in all cases, owing to the length or crookedness of the burrows. Bisulphid of carbon should then be used.

*Electric lights.*—To what extent electric lights are serviceable as an agency in the destruction of the moths of this borer has not been definitely determined. Col. Nicholas Pike and Dr. J. B. Smith, however, have advised placing shallow pans around electric-light poles in and around parks to attract the moths. The pans are partially filled with water and a few drops of kerosene are poured into them. The moths flying against the globes drop into the pans and are promptly killed when they come into contact with the oil. In this way many males can be destroyed.

*Inspection.*—In large parks the destruction wrought by this borer annually is an important item, and it will be found a source of profit to establish a system of inspection consisting in the employment of parkkeepers and boys, and others who may be engaged at lower

[a] During the last years of the nineteenth century a long row of beautiful red oaks bordering the street between the grounds of the Department of Agriculture and those of the Smithsonian Institution were badly infested by the related carpenter worm (*Prionoxystus robiniæ* Forst.). Nearly every tree was infested and frequently two or three burrows showed near the tops of the trunks. Bisulphid of carbon was applied, as described above, and the holes closed with grafting wax. A year later no insects could be found at work, but wherever this remedy had been applied a small scar remained. Two years later these had entirely disappeared and the trees looked as if they had never been infested.

wages, to keep a constant lookout for evidences of borer attack on valuable trees. On this head Southwick has reported that in 1893 he spent two months in fighting this insect alone in the city parks of New York, collecting wagon loads of limbs and branches and destroying the larvæ or pupæ.

*Maintaining trees in thrifty condition.*—If valuable trees are to be protected, the insect should not be allowed to breed in useless growth. The borers in such trees should be destroyed or the trees promptly felled and burned. Care should be exercised in transplanting new trees, and fertilizers should be used in order that the trees may be always thrifty, the better to withstand attack. This means protecting them from the attack of aphides, scales, and defoliators, such as tussock moths and the fall webworm, and keeping them free from disease.

Finally, in the control of this species promptness and thoroughness can not be too strongly emphasized. The bisulphid of carbon remedy should always be used where applicable, and the inspection system advised should be instituted in all public parks and on city streets infested by this pest. Individual owners of valuable trees should become acquainted with the pernicious nature of this borer, and united action should be secured with neighbors who also suffer from the ravages of the pest.

NOTE.—After this publication was in type we received information that trees in the college yard of Harvard University, Cambridge, Mass., are being severely injured, the large elms being the most seriously attacked.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *May 27, 1909.*

[Cir. 109]

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CIRCULAR No. 110. Issued July 10, 1909.

# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE GREEN-STRIPED MAPLE WORM.

(*Anisota rubicunda* Fab.)[a]

By L. O. Howard and F. H. Chittenden.

### GENERAL APPEARANCE AND METHOD OF WORK.

Maple trees grown in the United States for shade or other purpose are subject to severe injury from defoliation by caterpillars. In addition to the fall webworm[b] and tussock moth caterpillar[c] there is a common and troublesome species known as the green-striped maple worm (*Anisota rubicunda*) which affects maples of all kinds, including sugar maple, and is especially partial to silver and swamp maples. It feeds occasionally also on box-elder and will defoliate oak in the absence of its favorite food trees.

In its active stage this insect is a naked or hairless caterpillar (fig. 1, *d*, *e*) of large size and somewhat attractive appearance, being pale yellowish green, longitudinally striped with dark green. It is armed just back of the head, on the second thoracic segment, with a pair of long black horns. It has also a number of short, black, spiny projections along its sides and at its anal extremity. The anal segments are somewhat dilated and rose-colored on the sides. When fully grown, it measures nearly two inches in length.

The parent insect, or moth, is a beautiful creature of a pale yellow color shaded with a most delicate pink. The female is well shown in the accompanying illustration (*a*), the dark portions representing the pink, and the paler portions the yellow color. In eastern individuals the colors differ from those found in the West, the rose tints being more intense, while in the western forms the yellow predominates, with only a slight tinge of rose. Some western individuals also are nearly white. The female has a wing spread of one and three-fourths to about two inches, and her body is yellow and woolly in appearance. Her head is small, retracted into the thorax, and bears short, thread-like antennæ. The male is smaller than his mate, having plumose or feathery antennæ, as represented in the figure (♂).

The egg is about one millimeter in diameter, slightly flattened, and pale green, becoming yellowish before the larva hatches. A portion of

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[a] Formerly called *Dryocampa rubicunda* Fab.

[b] *Hyphantria cunea* Dru.

[c] *Hemerocampa* (*Orgyia*) *leucostigma* Dru.

an egg mass is figured in the illustration at *c*, and a much-enlarged egg with the embryo within at *b*. The pupa is very dark brown, nearly black, and of the somewhat peculiar form shown at *f*. It is armed with little spines on the margin of the abdominal segments and on the thorax, and the anal segment ends in a projection a little forked at the tip.

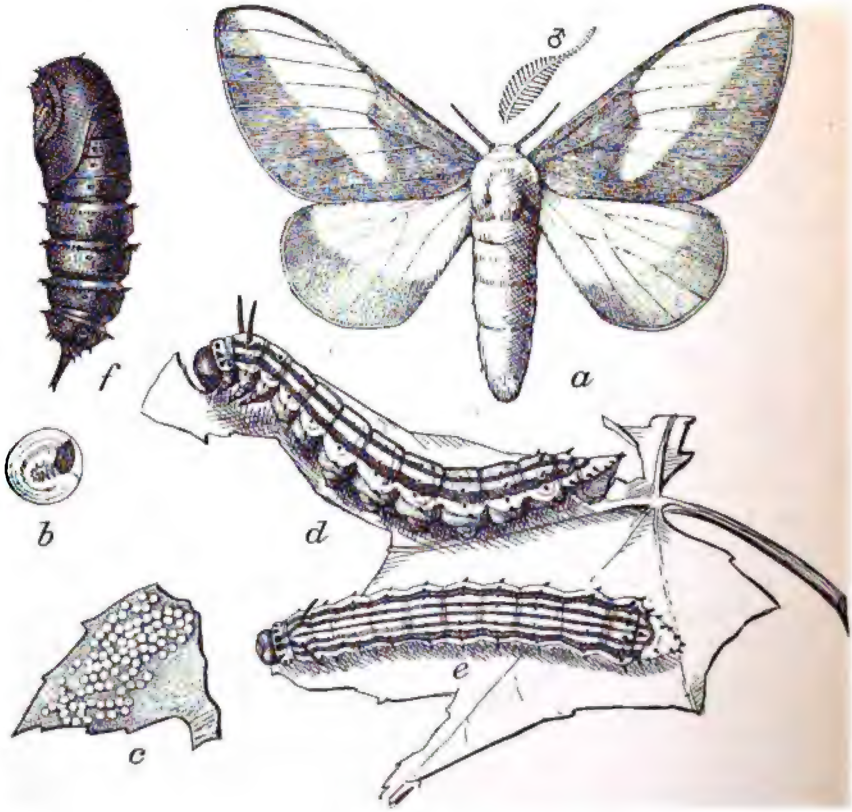


FIG. 1.—*Anisota rubicunda:* *a*, Female moth and antenna of male moth; *b*, egg showing embryo within; *c*, portion of egg mass; *d*, full-grown larva from side; *e*, same from back; *f*, pupa. Enlarged. (Original.)

ORIGIN AND DISTRIBUTION.

The green-striped maple worm is a native North American species and is more abundant in the West than in the East, although it enjoys a considerable range. It abounds especially in Kansas, Nebraska, Missouri, Illinois, and Iowa, occurring also in the Gulf States, occasionally doing considerable damage in Mississippi. It extends sometimes in injurious numbers North and East, and has attracted some attention by its ravages in West Virginia, the District of Columbia, New Jersey, and in a limited portion of New York State. Instances

are on record of its occurrence in great numbers in Dutchess and Sullivan counties in New York, but these occurrences were exceptional.

LIFE HISTORY AND HABITS.

The moths issue from over-wintering pupæ or chrysalides in May or June, according to locality, and pair, the females depositing their eggs on the under side of the leaves. The number of eggs laid by a single female has not been ascertained, but is known to reach at least 150. In eight or ten days the eggs hatch, and the caterpillar emerges and feeds and grows apace. After passing through four molts in about a month it reaches full growth, when it enters the ground to transform to pupa. At the end of two weeks, or a little longer, the pupa, by means of the sharp and horny projections which have already been described, works its way to the surface of the ground and gives forth the moth. Soon afterwards the female, after copulation, lays eggs for a second generation.

In the District of Columbia it has been ascertained that there are usually three generations in the course of a year, although in Missouri, according to Riley, there are only two. Pupæ of the second generation in the West and of the third generation in the East over-winter. Even as far north as Massachussetts Harris showed the probability of two generations annually.

INSTANCES OF INJURY.

Many of the earlier writers on economic entomology reported numerous instances of injury by this species, but of late the insect has not received much attention, presumably because of the far greater destructiveness of the commoner tussock moth and fall webworm, and of the gipsy and brown-tail moths. Possibly this maple worm is decreasing in numbers. Some characteristic outbreaks may be mentioned, therefore, as showing its importance some years and to give some idea of its method of work.

In 1887 Mr. H. W. Young, Independence, Kans., wrote that for four years the soft maple shade trees of that city had been defoliated twice a year by this insect, the trees being greatly weakened. In 1888 Mrs. M. T. McCluny, Sedalia, Mo., wrote that these "worms" "were like the locusts of Egypt, and filled the houses" and destroyed the leaves of the maple shade trees. In 1889 considerable correspondence was had with Mr. J. W. Merchant, Kansas City, Mo., who reported extensive defoliation in Kansas City, Kans., and sent several photographs, one of which is here reproduced (fig. 2). In cases where adjoining maple and elm trees branched into each other the elm trees were never touched. During the period from 1888 to 1890, at Lincoln, Nebr.,

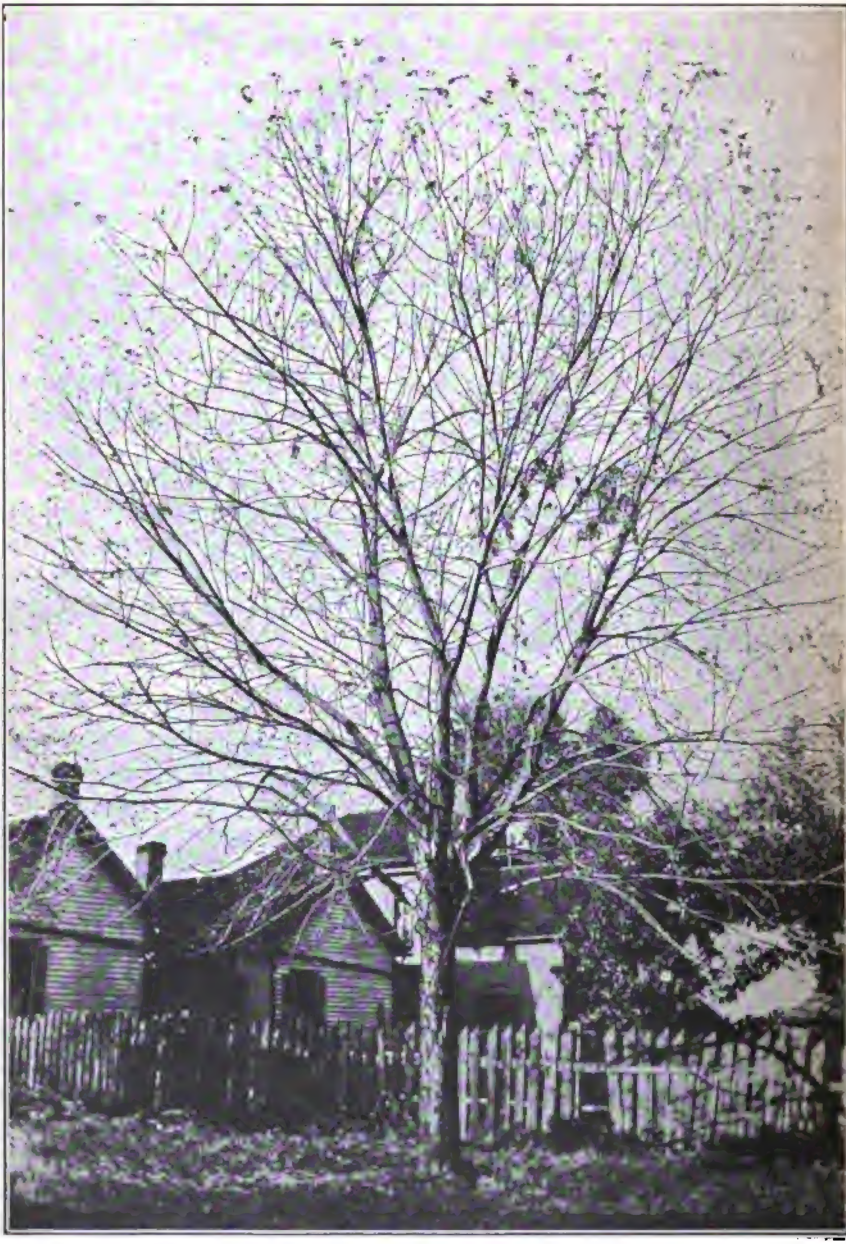

FIG. 2.—Maple tree at Kansas City, Kans., defoliated by green-striped maple worm. (Original.)

[Cir. 110]

many rows of large maples were entirely defoliated, rendering them very unsightly. (See fig. 3.) At about the same time Doctor Riley reported similar complete defoliation on the grounds of the State agricultural college at Manhattan, Kans., and of the State university at Lawrence, Kans. In 1901 Mr. F. E. Brooks reported great damage to the foliage of maple in the vicinity of French Creek, W. Va. Since 1905 the species has been abundant in portions of Maryland and Virginia, but not noticeably troublesome.

During 1908 it was devastating forests in and around Fryeburg, Me. At that time it almost entirely stripped maple and—it was said—oak, beech, birch, apple, and other deciduous trees over a very large section, but it seems probable that other species were present, as in other cases reported to this office.[a] It was particularly troublesome to shade maples in Maine, New Hampshire, and Pennsylvania.

### NATURAL ENEMIES.

The green-striped maple worm is frequently eaten by domestic fowls and by many birds. Of these the robin and yellow-billed cuckoo have been recorded by Bruner.[b] He reports both of these birds as actively engaged in picking up and swallowing the "worms" as late as September 20, at Lincoln, Nebr. The bluebird, tufted titmouse, red-headed woodpecker, red-eyed vireo, and crow blackbird are also stated by the late Prof. F. H. Snow to eat the "worms." while the moths also are sometimes destroyed by birds. To the above list Prof. F. E. L. Beal, of the Bureau of Biological Survey, adds the black-billed cuckoo and the great-crested flycatcher as enemies of this insect.

This species is parasitized by a common ichneumon fly, *Limnerium fugitivum* Say, a rather general parasite of lepidopterous larvæ. Two tachina flies have been reared from it, *Frontina frenchii* Will., from Washington, D. C., and vicinity, and *Belvosia bifasciata* Fab., from northern Missouri. Among the old Riley notes is a record of the rearing of an egg parasite, but the species has not been determined.

At one time the electric lights in some of the large cities mentioned were the means of attracting and destroying large numbers of the moths, and both moths and caterpillars were destroyed in large numbers by passers-by, who trampled on them.

As a rule little is to be expected from tachina flies as a means of controlling insect pests, and the ichneumon mentioned, being a general parasite, is not an efficient destroyer of this particular species. In

[a] The other species concerned in damage were *Heterocampa guttivitta* Walk. and *H. bilineata* Pack., principally to forest trees, although during the year they injured maple groves and attacked sugar maple and a considerable variety of the forest trees in New England.

[b] Lawrence Bruner, 1890, Bull. 14 Nebr. Agr. Exp. Sta., pp. 54–59.

FIG. 3.—State Capitol at Lincoln, Nebr., showing trees defoliated in 1890 by the green-striped maple worm.

other words, we can not rely for assistance upon any of the natural enemies except birds. These should be encouraged in every possible way, and warfare should be waged against the English sparrow, which does not feed on this caterpillar, save perhaps occasionally in nesting time, and is a great pest in itself, especially as it drives other and useful birds from cities and towns.

### REMEDIES.

*Arsenicals.*—Spraying with an arsenical mixture, if accomplished when the caterpillars are young, is the most effective means of controlling this insect, but a spraying is not easily applied when a large grove of maples is infested. Either Paris green or arsenate of lead may be used and applied in accordance with the directions furnished for other shade-tree defoliators, as described in detail in Farmers' Bulletin No. 99. This publication should be in the hands of all persons suffering from the ravages of shade-tree insects, and that portion relating to general instructions in the last chapter should be read.[a] Paris green may be applied on maple trees as strong as 1 pound to 50 gallons of water, but half that strength, or one-half pound to 50 gallons of water, will probably suffice in most cases. Arsenate of lead may be safely used at as high a rate as from 2 to 4 pounds of the poison to 50 gallons of water.

*Trenching.*—If an arsenical spray has not been used while the larvæ are young, large numbers of the pests may be trapped and easily destroyed by digging a trench either around individual trees or around groves or belts of trees. The trench should be at least a foot deep, with the outer walls sloping under. The larvæ usually wander away from the trees before entering the earth, and will be caught in the trench in great numbers or will bury themselves in the ground in the bottom of the trench, where they can be killed. This remedy was given a practical and thoroughly satisfactory test many years ago by Doctor Riley, and has been recommended to our correspondents generally.

*Hand picking.*—When the public once becomes well acquainted with this insect in all of its stages, from the egg to the moth, large numbers of the eggs and the moths can be killed by hand on their appearance in May or June, and individual choice trees may in a measure be protected in this manner.

Approved:

JAMES WILSON,

*Secretary of Agriculture,*

WASHINGTON, D. C., *May 26, 1909.*

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[a] Farmers' Bulletin No. 99 is furnished gratis on application to the Department of Agriculture.



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CIRCULAR No. 111. Issued September 29, 1909.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# PREPARATIONS FOR WINTER FUMIGATION FOR THE CITRUS WHITE FLY.

By A. W. MORRILL and W. W. YOTHERS.

## INTRODUCTION.

As a result of investigations conducted by the Bureau of Entomology during the past three years, fumigation for the citrus white fly has been placed upon a practical basis, and the process has been so simplified that any citrus grower can undertake the treatment of his grove without depending upon experienced fumigators to conduct the operations. Under present conditions fumigation is the most satisfactory and profitable method of controlling the white fly in hundreds of infested groves in the Gulf coast citrus-growing regions, and its usefulness will be extended to nearly all infested groves when the practical recommendations in a forthcoming bulletin on the white fly have been put into effect. The superior quality of Florida citrus fruits when grown in groves free from injury from insect pests and the awakening of progressive growers to the necessity for organizations for combating insect pests and for marketing the fruit point to the general adoption of the control measures to be recommended in the publication referred to.

At the present time the authors would recommend fumigation for the white fly under the following circumstances: In groves isolated by a distance of at least 200 yards [a] from all other infested groves, in citrus groves or in citrus-growing sections where the white fly has recently appeared and is still of limited distribution, and in sections where cooperation can be secured among growers in naturally isolated groups. In many cases the owner of an extensive and valuable grove which is isolated except for a small grove of a few acres from other infested groves can well afford to loan his equipment, or, if necessary, fumigate the neighboring grove entirely at his own expense,

[a] Experience so far has shown that as a rule in cases of isolation of much less extent fumigation can be practiced without its being rendered unprofitable through the migration of adults.

rather than to permit the presence of such grove to interfere with his results.

Full directions concerning equipment, chemicals, and methods of procedure in fumigating for the citrus white fly have been published in a bulletin of this Bureau.[a] This bulletin is based upon results obtained in January and February, 1907. Extensive field experiments have been conducted during the last two seasons and the additional results obtained will be embodied in a supplementary report now in preparation by the authors of this circular. It is hoped that before the beginning of the next fumigating season, extending from December 1 to March 1, a publication in the Farmers' Bulletin series of this Department will be available. This bulletin will contain only such advice and directions as are of practical importance in fumigation work against the white fly, omitting the details of experiments published elsewhere as the necessary basis for establishing practical conclusions. The present circular aims to call attention to the desirability and in most cases necessity for early preparations where fumigation work is planned for the coming winter season; also to give full directions for such preparations.

## EQUIPMENT.

### TENTS.

Orders for tents should be placed as soon as possible after it is decided to fumigate a grove. Tent makers do not always have on hand a sufficient quantity of desirable grades of canvas to fill large orders. Delays in filling the order may necessitate shipment by express, at a cost several times the expense of shipment by freight.

The first step is the determining of the sizes of tents required. It is a more common mistake to underestimate the size of a tent required than to overestimate it. Some allowance should be made for the growth of trees, in consideration of the future use of the tents. If the trees are nearly uniform in size, the largest trees should be selected for measuring. A tape measure attached to a reel is used in measuring trees to determine the size of tent required. Standing a few feet from the outside branches of the tree to be measured, enough of the tape is unreeled to extend over the top of the tree and about half way to the ground on the other side, the free end of the tape is held in one hand and the reel is thrown over the center of the tree and unreels the tape by its own weight until it reaches the ground. Two or three attempts may be necessary in order to have the tape pass over the center of the tree. It should be borne in mind that the weight of the tent will reduce the extreme height of the tree and that

[a] Bul. 76, Bur. Ent., U. S. Dept. Agr., Fumigation for the Citrus White Fly as adapted to Florida conditions. By A. W. Morrill.

it is therefore unnecessary for the tape to pass over the highest twigs. For large trees 6 to 8 feet should be added to the number of feet over the top of the tree, as shown by the measurement, and for small trees 4 to 6 feet should be added. In general, trees from 10 to 15 feet high require tents between 32 and 44 feet in size[a]; trees from 16 to 20 feet high require tents 44 to 58 feet in size; trees 21 to 25 feet high require tents 60 to 70 feet in size; and trees 25 to 30 feet high require tents 70 to 76 feet in size.

In regard to the number of tents required, it is safe to estimate that with one tent for each 100 trees the work of fumigation could be completed in ten to fourteen nights' work. One crew can handle from twenty to twenty-five small tents, 45 feet in size and smaller, and from eight to fifteen tents, 50 feet in size and larger. Much depends upon the trees being so spaced as to obviate interference with the work of shifting the tents.

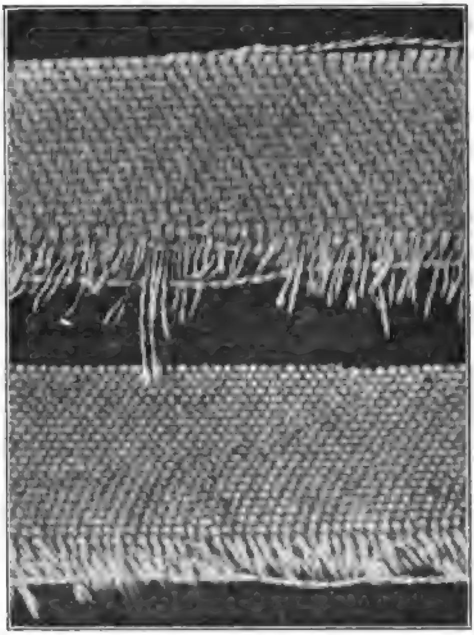

FIG. 1.—An undesirable and a desirable type of 8-oz. cotton duck for fumigating tents. (Original.)

Having decided upon the number and sizes of tents required, orders should be placed as soon as possible. Samples of 8-ounce army duck should be obtained from tent and awning makers who are in a position to furnish the tents. The selection of tent material is a matter of great importance. Samples of duck can be classified roughly in regard to tightness by the general texture and by the degree of imperviousness to direct rays of light when held between the eye and the sun, or any bright light. Neither of these methods is entirely satisfactory, however, in selecting material for fumigating tents. With a simple arrangement devised by the authors for testing the tightness of material submitted to the laboratory at Orlando, Fla., for examination, it has been found that samples of duck vary nearly 50 per cent in their comparative tightness.

Figure 1 illustrates two extreme samples of 8-ounce duck which differ to the extent of 47 per cent in this respect. As a result of

[a] The size of tents is expressed in terms of the distance between parallel sides of the octagonal sheet of canvas of which the tent is composed.

the examinations made so far, the authors strongly advise against the use of drills of any kind. The appearance of these is much more misleading than that of ducks, and it seems impossible to estimate their comparative tightness except by tests with special apparatus. Our experience up to the present time leads us to recommend closely woven duck weighing 8 ounces per yard, when 28½ or 29 inches wide, or about 10 ounces per yard when the material is 36 inches wide. The more expensive grades of cloth are not always the most nearly gastight. In the case of two leading concerns which have supplied large orders of tents for use in Florida, the medium grades of material, as shown by the prices quoted, have been found to be superior in gas-holding qualities to either the cheapest or the most expensive of the three grades upon which prices were quoted.

The form of cover which is at present almost exclusively employed is the flat octagon. Frequently those who have never seen a tent of this kind fail to realize its simplicity. A square piece of canvas would answer the purpose as well as the octagon, but to save material and the handling of extra cloth the corners of the square are left off. A perfectly circular cover would be more economical in respect to the amount of cloth required, but the saving would not cover the extra expense of construction in this form.

For specifications tentmakers may be referred to Bulletin 76 of this bureau.[a] In general these specifications are simply that the form is approximately octagonal, of any desired size, made of parallel strips of goods overlapped three-eighths or one-half inch, double stitched, and all raw edges hemmed. In the case of tents 50 feet or more in size a reinforcement is desirable across the middle section near each end, as described in the bulletin referred to. It is desirable that allowances be made for shrinkage, otherwise a tent after becoming wet and later drying may not be sufficiently large to cover trees of the size for which it was intended. The following published statement by the senior author is of importance in this connection and is quoted in full:[b]

Shrinkage of the goods after being thoroughly wet is an important consideration in the economical construction of fumigating tents. In order that the tents approximate a regular octagon, after having been used for fumigating purposes, it is necessary either to have the goods thoroughly shrunk before cutting or to make allowance for subsequent shrinkage by cutting the strips longer. A test made with a brand of 8-ounce duck commonly used in California for fumigating tents showed that the shrinkage lengthwise of the goods amounted to 7.5 per cent and crosswise 0.9 per cent. This means that in a 50-foot tent the shrinkage would result in the full-length strips shortening 3¾ feet, while the tent would shrink less than 6 inches crosswise of the strips. Such irregularities might be remedied by a skirt of 6½-ounce drill, but it is simpler to

[a] For sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 15 cents.

[b] Bul. 76, Bur. Ent., U. S. Dept. Agr., pp. 17–18.

plan to have each strip cut longer by a given amount for each 1 per cent of difference in the lengthwise and crosswise shrinkage. In the case referred to above this difference is 6.6 per cent, and each per cent represents an actual difference of 6 inches. A 50-foot tent constructed in this manner would therefore measure before shrinkage 52¼ feet (49 feet 10½ inches + 3 feet 4 inches) lengthwise of the strips through the middle section, and 49 feet 10½ inches crosswise of the strips. After shrinking, the dimensions would be approximately 49 feet 4½ inches in each direction.

On account of the variation in the shrinkage of different brands of duck it is necessary to test the crosswise and lengthwise shrinkage in the sample selected. This may be done by marking, with a lead pencil, lines 1 foot or more in length, both crosswise and lengthwise of the strip of goods. The sample should be shrunken twice, each time wetting by submerging in water for two or three hours and drying in the sun. The amount of the shrinkage can then be determined by measuring the pencil lines just referred to.

The marking of the tents with graduated stripes, which is a part of the process of determining dosage requirements originated by the senior author,[a] requires less than an hour for each tent. The necessary preparations for this, therefore, consist in procuring suitable paint and arranging for a patch of open field where the tents may be spread flat to become saturated with rain or dew, thus producing the desired shrinkage. The importance of the tents being thoroughly shrunken before the measuring for the graduations is obvious.

Directions for "mildew-proofing" the tents will be given in publications now in preparation and it is not necessary to include them in this connection. Tents should be thoroughly dried in the sun before being folded for storage, and in preparing them for field use they should not be exposed to rains or dews any more than is necessary to shrink as advised above.

### POLES AND DERRICKS.

In the Gulf States, seasoned cypress is probably the best material available for the manufacture of poles and derricks used in shifting tents. These serve practically the same purpose, the former being used in handling tents up to 50 feet in size and the latter in handling tents 50 feet in size and larger. The poles have no other attachment than a rope, while the derricks each consist of a pole with a crosspiece and braces at the base and eye-bolt attachment for pulley and tackle at the small end. These poles and derricks can be prepared for use in a short time, but it is very important that the poles be cut and peeled long enough before they are needed for use to permit them to become well seasoned. Poles should be carefully selected in order to have them as straight and free from knots as possible. While only two poles or two derricks are needed for use at one time, an extra supply of both should always be in readiness,

[a] Loc. cit., pp. 32–33.

so that in case of breakage the work can be continued with little interruption. The length of the shifting poles should be about 2 feet more than the height of the average trees, and the small end should be about 1½ inches in diameter. The poles for derricks should be about 3 or 4 feet more in length than the height of the average tree, and when ready for use should be between 3 and 4 inches in diameter at the base and between 2 and 3 inches in diameter at the top. The method of attaching the crosspieces and braces is described and illustrated in Bulletin 76 of this Bureau. If ordinary three-eighths or one-half inch bolts are at hand, a pair of derricks can be prepared for use in less than half an hour, and this need not therefore be considered a necessary part of the early perparations for fumigation. Cypress poles should be seasoned in a barn or packing house, or if out of doors they should be in the shade. Straight poles, while being seasoned, should be so supported as to prevent bending or warping. If, after cutting, a pole is found to be crooked, it may perhaps be made practically straight by the proper arrangement of the supports when seasoning.

#### GENERATORS OR CROCKS.

In generating the gas earthenware crocks are used. In general, trees 5 to 8 feet high will require crocks of 1½ gallons capacity; trees 9 to 12 feet high, crocks of 2 gallons capacity; trees 13 to 16 feet high, crocks of 4 gallons capacity; trees 17 to 20 feet high, crocks of 4 or 5 gallons capacity; and trees 21 to 30 feet high, crocks of 5 or 6 gallons capacity. For trees up to about 18 feet in height one crock will be needed for each tent, but for larger trees two crocks should be used, dividing the dosage into two equal parts. Crocks with straight sides can be used with more cyanid for each gallon of capacity than crocks which narrow at the top, and it is to the former style rather than to the latter that the preceding statements refer.

The foregoing directions should enable anyone preparing to fumigate to determine the actual number and sizes which will be needed. It is always advisable to have several extra crocks at hand, so that delays will be avoided in case of breakage.

Crocks of more than 2 gallons capacity can not be readily obtained as a rule and frequently even the smaller sizes can not be obtained of local dealers in sufficient numbers to equip a large outfit. It is important, therefore, that orders for crocks be placed as soon as possible when preparing to fumigate. As the tops or covers are not needed, dealers should take this into consideration in quoting prices. When not purchased of local dealers and no allowance is made in the price on account of the covers of the crocks, instructions should be given not to include the covers in the shipment, in order to avoid unnecessary freight or express charges.

Convenient handles for the crocks can be made of a large size[a] of wire. If properly arranged the ends of the handle will be held in position on opposite sides of the crock, otherwise they may cause considerable annoyance.

### MISCELLANEOUS REQUIREMENTS.

Of the numerous articles of minor importance which sometimes are not easily obtained and should therefore be arranged for as early as possible are rubber gloves and glass graduates. Two or three pairs of rubber gloves should be obtained for a large outfit. One pair is needed for the one who measures the acid and generates the gas, and one pair should be available for use by the helper who empties the contents of the crocks after fumigating. The third pair should be on hand in case one of the pairs in use is lost or destroyed by any means. Rubber gloves can be purchased of or ordered through electrical supply houses or electric-light companies. Black rubber gloves with cloth lining are preferable to the red rubber gloves without lining which are sometimes used. The latter are not easily removed from the hands, especially after they become wet on the inside, and are on this account very troublesome. One should avoid gloves which are so thick that a wet glass graduate can not be easily handled when wearing them.

A glass graduate of 16 ounces capacity is needed for each outfit, and if not obtainable of local dealers one or two extra ones should be always on hand. They can be purchased through local druggists or directly of wholesale drug houses. It is important that the numbers on the graduate be plain and easily readable.

Torches are preferable to lanterns, and if possible three or four of the former should be obtained.

Balances, stoneware pitchers, dippers, water buckets, ropes, pulleys, and other articles can usually be obtained of local merchants.

## CHEMICALS.

The chemicals required in fumigation with hydrocyanic-acid gas are potassium cyanid (KCN) and sulphuric acid ($H_2SO_4$).

### POTASSIUM CYANID.

The cyanid ordinarily used in fumigating citrus trees is put up in 200-pound cases and costs between 21 and 23 cents a pound in ton lots. It should be guaranteed to be 98 to 99 per cent pure. In calculating the amount of cyanid required, a tree should be selected which represents as nearly as can be estimated the average size of the trees in the grove. The distance over the top can be obtained by the tape measure in the same manner as described in connection with estimating the sizes of tents required. In addition to this measurement the circumference of the tree should be measured with the

[a] No. 9 has been used by the authors for this purpose.

tape line. This can be done by attaching the free end of the tape to a twig and passing around the tree, hanging the tape on the outer twigs as it is unreeled. If the grove consists of two sizes of trees, as, for example, large seedling and medium-sized budded trees, an average specimen of both kinds should be measured. The amount of cyanid required for these average specimens can be determined from the dosage table given herein. The following examples illustrate the method of using the table after the distance over and the circumference of the tree have been obtained:

| Example No. | Distance over tree. | Circumference of tree. | Amount of potassium cyanid required. |
|---|---|---|---|
| | *Feet.* | *Feet.* | *Ounces.* |
| 1 | 24 | 40 | 9 |
| 2 | 38 | 55 | 26 |
| 3 | 52 | 72 | 58 |
| 4 | 66 | 79 | 96 |

The amount of cyanid in ounces having been obtained for the average tree in the grove, this amount is multiplied by the total number of trees to be treated and divided by 16 to reduce to pounds. It is advisable to obtain from 5 to 10 per cent more cyanid than the amount estimated, in order to avoid delays in case of underestimation. The cyanid, being put up in air-tight tin cases inclosed in stout wooden boxes, may be stored for months without deterioration. Excess cyanid can usually be disposed of without difficulty.

SULPHURIC ACID.

Sulphuric acid can be purchased in iron drums containing about 1,500 pounds at about 1 $\frac{1}{10}$ cents a pound. One drum of acid is required for about 4 cases of cyanid. The acid should be guaranteed 66° Baumé or 93 per cent pure. It is advisable to have a sample tested with an acid hydrometer, an inexpensive instrument which can be obtained through any druggist. Acid should not be stored for more than two or three weeks in the drum. Unless it is to be used at once the entire contents should be emptied into carboys, the mouths of which should be closed with wooden plugs, strips of burlap, and plaster of Paris. Empty carboys can be purchased for $1.50 or $1.75 each, and 9 are required to contain the contents of an acid drum. Only carboys in good condition should be used, since the container is made of thin glass and breaks easily if the bottom of the wooden case becomes weakened and fails to support the contents. Great care should be used in handling the acid. Probably the quickest and safest way of emptying acid from the large drum into carboys is a method which has been used on several occasions by the authors. The drum is mounted on two heavy planks resting on the ground and is arranged so that it can be rolled forward and backward easily. At one end of

the planks a pit about 3 feet deep is dug. This should be large enough for two men to stand in and place the empty carboy in position and lift it out when filled. A large-mouthed funnel made of sheet lead is placed in the mouth of the carboy. A piece of cast-iron piping about 6 or 8 inches long and properly threaded is a convenience, but not a requirement. This, if available, is screwed into the opening in the drum, which is arranged so that the acid will pour into the funnel leading to the carboy. A piece of heavy plank or other suitable lumber should be strongly spiked across the ends of the two plank supports of the drum to prevent its being rolled too far forward. Whenever there is a suitable platform available, or timber is available for making a rough one, the trouble of digging the pit can be obviated. It is not

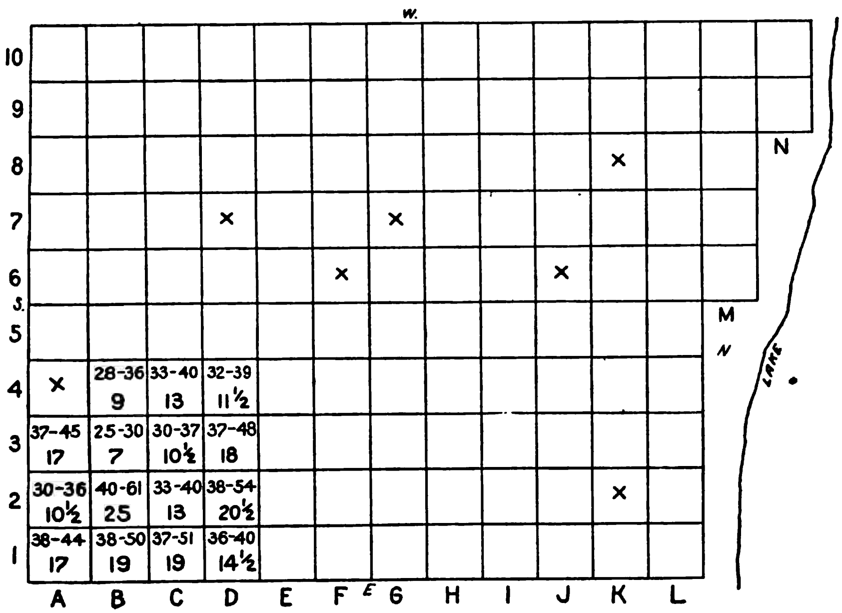


FIG. 2.—Diagram of regularly set grove in process of fumigation with an outfit of four tents: X, X, trees missing. (From Morrill.)

advisable to empty drums from railroad stations or packing-house platforms, as more or less acid is usually spilled. No one should stand near the carboy when the acid is being poured, and care should be taken to prevent any spattering of the acid from reaching the face. When handling acid it is always well to have water at hand for use in case of accident. With proper care sulphuric acid can be handled without danger of any kind.

DIAGRAMS OF GROVES, AND DOSAGE TABLES.

While it is not always necessary that diagrams of groves be made, it is always advisable as a matter of record and to prevent errors. Figures 2 and 3 illustrate methods of making diagrams when trees

are set in the square and in the alternate system, respectively. The figures in the squares represent the records of the trees fumigated, the two upper figures separated by a dash representing the dimensions of the tented tree and the lower figure the amount of cyanid given.[a] These records are made at the time each tree is fumigated.

In presenting the dosage table recommended in Bulletin 76 it was stated that the amounts of cyanid could be increased from 10 to 25 per cent with advantage under certain conditions. At the present time the authors advise for general use a table (fig. 4) representing

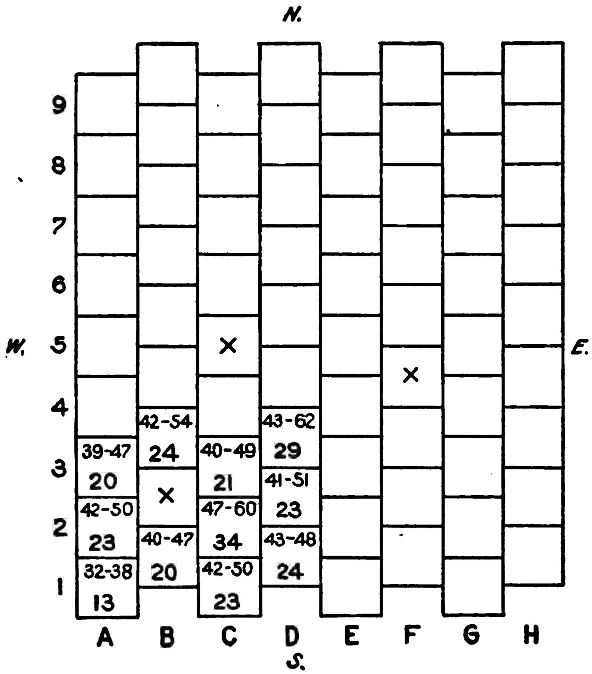


Fig. 3.—Diagram of grove with alternating trees; first four rows in process of fumigation with four tents; three sets of trees fumigated, the tents being moved from south to north: X, X, X, trees missing. (From Morrill.)

an increase of 25 per cent over the minimum requirements previously given in tabular form. This seems desirable, owing to the wide variations in the weave of various tenting materials and to the frequency with which slight winds might interfere with the results.

## MISCELLANEOUS SUGGESTIONS.

With the gradual extension of the process of fumigation in the control of the white fly in Florida and other citrus-growing sections of the Gulf coast, the value of a citrus grove will be considerably

[a] The amount is according to the dosage table given in Bulletin 76 of this Bureau, page 68.

affected by the difficulties in fumigation presented by excessive height of trees, closeness of planting, unevenness of ground, and other conditions. The systematic treatment of groves to overcome these difficulties, so that the trees may be easily fumigated, will not only be of value in this respect, but will constitute a good cultural practice. Trees planted too closely for fumigation to be practicable are too close for best results in productiveness. Limiting the height of trees by pruning not only lessens the expense of fumigation, but reduces the expense of picking the fruit without reducing the quantity.

| Distance | | CIRCUMFERENCE. | | | | | | | | | | | | | | | | | | | | | | | | | Distance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Over | | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | Over | |
| 1 | 10 | 2 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | 10 | 1 |
| | 12 | 3 | 3 | 3 | | | | | | | | | | | | | | | | | | | | | | | 12 | |
| | 14 | 3½ | 3½ | 3½ | 3½ | | | | | | | | | | | | | | | | | | | | | | 14 | |
| | 16 | 4 | 4 | 4 | 4 | 4 | | | | | | | | | | | | | | | | | | | | | 16 | |
| | 18 | | 5 | 5 | 5 | 5 | 5 | | | | | | | | | | | | | | | | | | | | 18 | |
| | | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 2 | 20 | | 5½ | 5½ | 5½ | 5½ | 5½ | | | | | | | | | | | | | | | | | | | | 20 | 2 |
| | 22 | | | 5½ | 6½ | 6½ | 6½ | 7 | | | | | | | | | | | | | | | | | | | 22 | |
| | 24 | | | 6½ | 7½ | 7½ | 8 | 9 | 9½ | | | | | | | | | | | | | | | | | | 24 | |
| | 26 | | | | 9 | 9 | 9½ | 10 | 11 | | | | | | | | | | | | | | | | | | 26 | |
| | 28 | | | | 10 | 11 | 11 | 12 | 13 | 13 | | | | | | | | | | | | | | | | | 28 | |
| | | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 3 | 30 | | | | | 12 | 13 | 13 | 14 | 15 | | | | | | | | | | | | | | | | | 30 | 3 |
| | 32 | | | | | 13 | 14 | 15 | 16 | 18 | 19 | | | | | | | | | | | | | | | | 32 | |
| | 34 | | | | | 15 | 15 | 16 | 18 | 19 | 21 | 23 | | | | | | | | | | | | | | | 34 | |
| | 36 | | | | | | 17 | 18 | 19 | 21 | 22 | 23 | 25 | | | | | | | | | | | | | | 36 | |
| | 38 | | | | | | 19 | 20 | 21 | 23 | 24 | 26 | 27 | 28 | | | | | | | | | | | | | 38 | |
| | | | | | | 30 | 35 | 40 | 45 | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 4 | 40 | | | | | | | 22 | 23 | 26 | 27 | 28 | 30 | 31 | 32 | | | | | | | | | | | | 40 | 4 |
| | 42 | | | | | | | 23 | 26 | 28 | 30 | 31 | 32 | 33 | 35 | 36 | | | | | | | | | | | 42 | |
| | 44 | | | | | | | | 28 | 30 | 31 | 33 | 35 | 36 | 37 | 39 | 40 | 42 | | | | | | | | | 44 | |
| | 46 | | | | | | | | | 33 | 34 | 36 | 37 | 39 | 40 | 42 | 43 | 45 | 47 | 49 | | | | | | | 46 | |
| | 48 | | | | | | | | | 35 | 37 | 38 | 39 | 42 | 43 | 45 | 47 | 48 | 50 | 51 | 53 | | | | | | 48 | |
| | | | | | | | | 40 | 45 | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 5 | 50 | | | | | | | | | | 39 | 41 | 43 | 45 | 46 | 49 | 51 | 53 | 55 | 57 | 58 | 60 | | | | | 50 | 5 |
| | 52 | | | | | | | | | | | 43 | 45 | 47 | 49 | 51 | 53 | 56 | 58 | 60 | 62 | 64 | 66 | | | | 52 | |
| | 54 | | | | | | | | | | | 46 | 48 | 50 | 53 | 55 | 58 | 60 | 62 | 64 | 66 | 68 | 70 | 73 | | | 54 | |
| | 56 | | | | | | | | | | | | 51 | 53 | 56 | 58 | 61 | 63 | 66 | 68 | 71 | 73 | 75 | 77 | 79 | | 56 | |
| | 58 | | | | | | | | | | | | 53 | 56 | 59 | 61 | 64 | 67 | 70 | 72 | 75 | 78 | 80 | 82 | 84 | | 58 | |
| | | | | | | | | | | 50 | 52½ | 55 | 57½ | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 6 | 60 | | | | | | | | | | | | | 60 | 63 | 65 | 68 | 70 | 73 | 76 | 79 | 82 | 85 | 88 | 91 | 94 | 60 | 6 |
| | 62 | | | | | | | | | | | | | 62 | 65 | 68 | 72 | 75 | 78 | 80 | 83 | 86 | 89 | 91 | 94 | 97 | 62 | |
| | 64 | | | | | | | | | | | | | 66 | 69 | 72 | 76 | 79 | 82 | 85 | 89 | 92 | 95 | 98 | 101 | 104 | 64 | |
| | 66 | | | | | | | | | | | | | 69 | 73 | 76 | 80 | 84 | 87 | 89 | 93 | 97 | 101 | 104 | 107 | 111 | 66 | |
| | 68 | | | | | | | | | | | | | 73 | 77 | 80 | 84 | 87 | 90 | 93 | 97 | 101 | 105 | 109 | 113 | 116 | 68 | |
| | | | | | | | | | | | | | | 60 | 62½ | 65 | 67½ | 70 | 72½ | 75 | 77½ | 80 | 82½ | 85 | 87½ | 90 | | |
| 7 | 70 | | | | | | | | | | | | | 77 | 80 | 83 | 87 | 90 | 94 | 98 | 102 | 106 | 110 | 114 | 118 | 123 | 70 | 7 |
| | 72 | | | | | | | | | | | | | 80 | 83 | 86 | 90 | 94 | 98 | 103 | 107 | 111 | 115 | 119 | 123 | 127 | 72 | |
| | 74 | | | | | | | | | | | | | 84 | 87 | 89 | 94 | 98 | 103 | 107 | 112 | 116 | 120 | 124 | 128 | 133 | 74 | |
| | 76 | | | | | | | | | | | | | 87 | 90 | 94 | 98 | 102 | 107 | 112 | 117 | 121 | 125 | 129 | 134 | 139 | 76 | |

FIG. 4.—Dosage schedule for use in fumigating for the citrus white fly. (Original.)

In preparing for the fumigation of a grove, if the branches interlock to any extent, either pruning of branches or transplanting of alternate trees or rows of trees is advisable. Deadwood on the outer parts of the trees should be thoroughly removed in all cases to avoid the tearing of tents. Watershoots should be thoroughly removed at the same time, since about 1 per cent of the white fly pupæ present during the winter months survive fumigation and the resistance of the insects on watershoot leaves is much greater than elsewhere on the trees.

If possible, the cultivating and fertilizing of groves to be fumigated should follow fumigation. It is much more difficult to handle the fumigating tents on newly cultivated ground, and the dust arising in the shifting of the tents is sometimes a matter of considerable discomfort to the men engaged in the work.

Approved:

W. M. Hays,

*Acting Secretary of Agriculture.*

Washington, D. C., *August 10, 1909.*

[Cir. 111]

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# CONTROL OF THE MEDITERRANEAN FLOUR MOTH BY HYDROCYANIC-ACID GAS FUMIGATION.

By F. H. CHITTENDEN, Sc. D.,

*In Charge of Truck Crop and Stored Product Insect Investigations.*

### INTRODUCTORY.

Until in somewhat recent years flour mills in the United States were little troubled with injurious insects. It is true that weevils and other granary pests were brought into the mills with grain, and in the course of time many mills have become infested with flour beetles.[a] Beginning with the year 1892, however, several Cali-

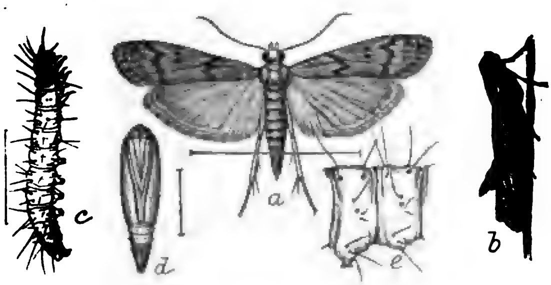


FIG. 1.—Mediterranean flour moth (*Ephestia kuehniella*): *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. *a–d*, Enlarged; *e*, more enlarged. (Author's illustration.)

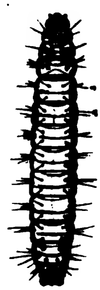

FIG. 2.—Mediterranean flour moth: Larva, dorsal view. (Author's illustration.)

fornia mills became infested by the Mediterranean flour moth (*Ephestia kuehniella* Zell.), which has been aptly called "the scourge of the flour mill" and the "winged gray plague." At first its progress in this country was slow, but in less than a decade it had become recognized as a most serious pest in many States, and at the present time it is known to occur in practically all of our principal milling centers, and in most of our States from the Atlantic to the Pacific and from Canada to Mexico.

[a] Chiefly species of Tribolium, Cænocorse (Palorus), Gnathocerus, et al.

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*Descriptive.*—The adult insect is a phycitid moth with a wing expanse of a little less than an inch; the fore-wings are pale leaden gray, with transverse black markings of the pattern shown in the accompanying illustration (fig. 1, *a*); the hind-wings are dirty whitish, semitransparent, and with a darker border. The larva or caterpillar, illustrated at figure 1, *c*, *e*, and at figure 2, is whitish with minute black dots, and sparsely hairy. When full grown it measures about one-half an inch or a little longer (12.5–17.5 mm.). The chrysalis, shown at figure 1, *d*, is reddish brown.

*Distribution.*—Until the year 1877, when the moth was discovered in a flour mill in Germany, this insect was comparatively unknown. Later it invaded Belgium and Holland, and in 1886 appeared in England. Three years afterwards it made its appearance in destructive numbers in Canada. In 1892 it was reported injurious in mills in California, and in 1895 in New York and Pennsylvania.

From that time forward until 1904 the dissemination of the species was comparatively slow. In 1898 it had reached Minnesota, the next year Wisconsin; in 1900 it had greatly increased in Minnesota; two years later it invaded Michigan, and by 1904 it was reported in several other States, including Indiana, Illinois, Montana, Colorado, Ohio, and Iowa. In later times, each year has witnessed a similar increase in distribution, until now, in 1910, this flour moth is attracting more attention than any insect that ever infested mills or other buildings where cereals are stored; indeed, it is almost the sole topic of complaint of millers at the present writing, correspondence in regard to weevils and flour beetles, which was at one time heavy, having fallen off very noticeably.

*Ravages and habits.*—The caterpillars form cylindrical silken tubes in which they feed, and it is largely due to their habit of web spinning that they are so injurious where they obtain a foothold. Upon attaining full growth the caterpillar leaves its original silken domicile and forms a new web, which becomes a cocoon, in which it undergoes transformations to pupa and to imago. While searching for a place for transformation the insect is most troublesome. The infested flour becomes felted together and lumpy, the machinery becomes clogged, necessitating frequent and prolonged stoppage, and resulting in a short time, in large establishments, in the loss of thousands of dollars. A sample of matted flour is illustrated in figure 3, from a photograph by Mr. C. H. Popenoe.

As to the losses caused directly and indirectly by this insect it has been difficult to obtain estimates, the lowest being between $100 and $200 to a mill of 1,000 barrels capacity. The average loss due to closing down the mill and cost of treatment seems to be not far from $500 for each fumigation, "to say nothing of the loss to business," according to one Kansas milling firm. An estimate of $1,000

for two fumigations can not be far from right, although others estimate $2,000, while still others—owners of larger mills—claim it to be $5,000 a year. One prominent miller states that, aside from the cost

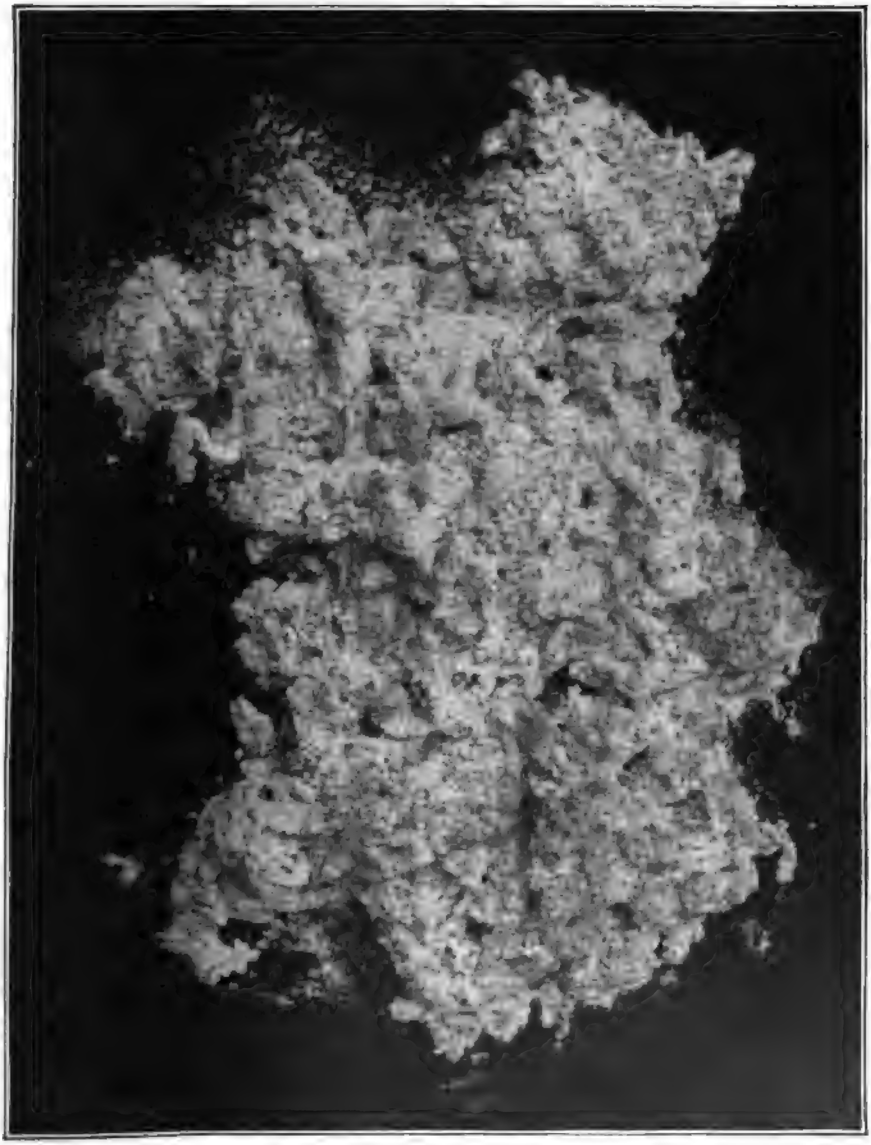

FIG. 3.—Matted flour showing the work of the Mediterranean flour moth. (Original.)

of fumigating, the loss due to stoppage while cleaning is incalculable, and expresses the opinion that some restrictions should be imposed on millers who do not clean and fumigate their mills.

Although the larva prefers flour or meal, it will attack grain when the former are not available, and it flourishes also on bran and prepared cereal foods, including buckwheat, grits, and crackers. It lives also in the nests of bumblebees and in the hives of the honey bee.

## FIRST USE OF HYDROCYANIC-ACID GAS AGAINST INSECTS IN STORED PRODUCTS.

The use of hydrocyanic-acid gas as a remedy for insects in mills and other inclosures where grain, flour, and similar products are stored was first suggested by the late W. G. Johnson in the American Miller for March, 1898, the incentive for its employment having been an invasion of cockroaches in a mill in North Carolina.

The first test of this method as a means of destroying insects in stored products was probably that made by the writer the same year.[a]

Additional experiments were soon afterwards made in conjunction with Mr. Pratt and the cost and the advantages and disadvantages carefully weighed, with the resulting conclusion that since hydrocyanic-acid gas is infinitely more dangerous to human life than bisulphid of carbon, as well as more expensive, its employment as a fumigant for ordinary insects injurious to stored products was less desirable. On this account no publication was made of the results nor was it, until recently, recommended to the numerous persons who inquired for remedies for mill pests. Soon after this first experiment a test to determine the availability of this gas against the Angoumois grain moth was made on a larger scale but with very imperfect success.[b]

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[a] March 5, 1898, the writer, with Mr. F. C. Pratt, then working under his direction, fumigated a lot of dried grain infested by the rice weevil (*Calandra oryza* L.) and a leguminous seed affected by a Bruchus or seed weevil, the material being placed in a moderately tight fumigating box. The cyanid of potash was purchased in open market and was used at the rate of 2 ounces to each 100 cubic feet. A quantity of acid slightly in excess of the salt was employed with twice that amount of water. The experiment began at 4 p. m. Saturday and was conducted in a building in which the temperature was usually from 70° to 76° F. The following Monday morning at 7.30, when the door was opened for airing, no odor was perceptible, and only a very slight trace of gas could be detected a half hour later when the box lid was removed. As a result all the seed weevils (Bruchus) loose in bags were found dead and all of the rice weevil, except a very few individuals, which revived after a few hours—less than 0.1 per cent—were killed.

[b] A lot of paddy or unhulled rice infested by this moth was desired to be fumigated and was placed in what appeared to be a nearly air-tight inclosure, a room specially prepared for the purpose. The cyanid was prepared in the usual way and was used at a strength of about 1 ounce to 100 cubic feet, but after the fumigation the insects were seen to be flying freely about the fumigating room. See Bureau of Entomology Cir. No. 46, entitled, "Hydrocyanic-acid Gas against Household Insects," by L. O. Howard, first issued in 1902, revised edition February 20, 1907. Note what is said in the footnote on page 2.

During 1899 mills were fumigated in Pennsylvania and Ohio, under the direction of Professor Johnson, with satisfactory results, and continued in later years by and under the direction of Professor Johnson as well as by Professor Washburn, State entomologist of Minnesota, Prof. H. A. Surface, State zoologist of Pennsylvania, and other State officials. In the course of time hydrocyanic-acid gas has come to be recognized as the best fumigant for the Mediterranean flour moth. It is equally valuable against related moths found in mills, but is less effective in destroying flour beetles and grain weevils, and even in the destruction of the Angoumois grain moth in corn. Indeed, it is not generally recommended for any of the latter pests.

From what subsequently has been learned of this method, failure in some cases was undoubtedly due to impure potassium cyanid and to faulty application of the process, since the fumigating vessels were rather small for the purpose and permitted a considerable boiling over at the top. Much residue also remained; in other words, the potassium cyanid was probably too weak, perhaps no stronger than 50 to 60 per cent pure, as was also the sulphuric acid, which was not used in sufficient quantity to produce a perfect gas, a considerable amount of cyanid remaining unaffected as solid residue in the generating vessel. It seems also probable that the cyanid was broken into too fine particles, but this detail can not now be remembered.

Owing to these failures as well as to those of other tests which were afterwards made, the suspicion arose that something was wrong with the ingredients. A sample of the cyanid used was submitted to the Bureau of Chemistry and treated with sulphuric acid, with the result that only 54.50 per cent of the amount of hydrocyanic-acid gas demanded by theory was found. Analysis showed 51.70 per cent potassium cyanid, 2.07 per cent sodium cyanid, and 39.28 per cent potassium carbonate, the remainder consisting of sodium chlorid or common salt and impurities. It will be noticed that this cyanid was little more than half as strong as demanded for perfect work; hence, what appeared to be a fumigation at the rate of 30 ounces to 1,000 cubic feet was in reality only about 16 ounces.[a]

[a] An instance of fumigation with impure cyanid of potash should be cited. During September, 1904, the writer, with Mr. Pratt, undertook the fumigation of a dwelling infested by the cigarette beetle (*Lasioderma serricorne* Fab.), using 1 ounce of cyanid to 100 cubic feet of space, which destroyed many beetles. Two weeks later, however, the beetles had again accumulated in numbers, showing that neither larvæ nor pupæ had been killed to any extent. Then 3 ounces of cyanid were used with a still longer exposure, a total of practically forty-two hours. This killed many larvæ which dropped from the furniture, the principal seat of infestation, although carpets were also affected, but many were probably not killed and certainly the eggs were not destroyed, as the insects continued to infest the house, with the result that before a third fumigation could be given the furniture was disposed of.

For particulars see pages 68–70, Bul. 54, Bur. Ent., U. S. Dept. Agr., 1905.

It should not be imagined that because this method is of value against the Mediterranean flour moth and related insects, and soft-bodied species like psocids or book-lice, which also occur in mills, that it is a sovereign remedy for other insects in mills and other inclosures. Quite the contrary; it has been found only partially effective and therefore unsatisfactory when used against grain weevils, flour beetles, and other hard-bodied insects, and the preparatory stages of the Angoumois grain moth, although effective in killing the adults of the latter. Indeed, not until very recent years has its use become generally recommended for the flour moth.

Mr. C. H. Popenoe, working under the writer's direction, in fumigating primarily for the flour moth, succeeded in killing many of the confused flour beetle (*Tribolium confusum* Duv.) in two applications at 4 ounces to 1,000 cubic feet. A larger percentage was destroyed by one application at the rate of 8 ounces, and so on up. Mr. D. K. McMillan had similar good success with 10 ounces.

In pamphlets published in 1904 Prof. F. L. Washburn has recommended hydrocyanic-acid gas for the treatment of the flour moth, stating the advantages of this treatment and giving details as to the penetrating power of the gas and other matters.[a]

As an instance of the successful use of hydrocyanic-acid gas, the experience of a Kentucky milling firm that was advised to use this method of fumigation may be briefly narrated.

In the city where this firm is located the species had been present in their mill four years, yet a few months prior to hearing from them the writer did not know of the insects' occurrence in that State. It had been introduced in second-hand machinery. Bisulphid of carbon had been used by them previous to their correspondence with the writer and was described as "no good except for weevils in stored grain." It had been employed at the rate of 300 pounds to 62,400 cubic feet of air space, or about 5 pounds to 1,000 cubic feet—fully twice as strong as necessary in an ordinary mill. Afterwards, by the writer's advice, hydrocyanic-acid gas was employed and the following report was made, August 24, 1909:

> Saturday, July 24, 1909, our mill was fumigated with hydrocyanic-acid gas, using 18 4-gallon jars, each charged with 3 pounds of cyanid of potassium, 4½ pounds of sulphuric acid, and 7 pounds of water. We killed moths and their eggs, worms and bugs of all kinds, wasps, mud-daubers, spiders, bats, rats, and mice, and also English sparrows perched outside on the roof. It has just been one month since we fumigated, and we see no more as yet. There is no sense in a miller being pestered with the flour moth. Hydrocyanic-acid gas will kill the moth and the eggs.

Our correspondents also wrote that in their opinion it would be difficult to operate any mill infested with the flour moth without

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[a] Ninth Annual Report State Entomologist of Minnesota, pp. 31–36, 1904; Special Report State Entomologist of Minnesota, February 29, 1904.

fumigation, as the cost of shutting down, cleaning machinery, etc., would destroy the profit. In this latter fumigation, 54 pounds cyanid of potash were used, equivalent to 13.9 ounces to 1,000 cubic feet, or about one-third more than necessary if the building was tight and the ingredients known to be pure.

### SUMMARY OF VALUE OF THE HYDROCYANIC-ACID GAS METHOD.

The special qualities of hydrocyanic-acid gas and some of the advantages which it possesses over other insecticides (as well as its disadvantages) as a fumigant for mills and other buildings infested by insects may be briefly summarized as follows:

1. It is generated without the aid of fire, in which respect there is a distinct advantage in its use in preference to sulphur fumigation, unless the Clayton process is employed.
2. It is practically noninflammable and nonexplosive in a large confined space when generated according to methods now in practice.
3. It is possible, therefore, to use this method of fumigation where with the employment of either bisulphid of carbon or sulphur a conflict with insurance companies might occur.
4. It is not injurious to cereals or other dried products in storage, either for food or for seed, in which respect it is superior to sulphur, which destroys the germinating qualities of seeds as well as plant life generally.
5. Fumigation may be employed at any time, night or day, but preferably in a moderately warm temperature and on a calm day without wind.
6. In a very short time after ventilation of the treated premises the characteristic "peach-pit" odor of the gas entirely disappears and, properly used, no solid residue remains in the generator.
7. Hydrocyanic-acid gas is lighter than air and has considerable penetrating power—not so great, however, as possessed by sulphur where forced into buildings and other inclosures by means of the Clayton process.
8. The gas, generated in air-tight inclosures, creates a positively deadly atmosphere, and thus used destroys most stages of the flour moth and some other insects. It is still more deadly at a much shorter exposure to man and other mammals, including domestic animals, rats, mice, and other vermin, than to mill insects.
9. It is the most powerful poison in common use, which fact being fully recognized, human beings are not readily tempted to run unnecessary risks of exposure to its deadly fumes.
10. The process is comparatively inexpensive under conditions which permit of buildings being made nearly gastight, especially when a complete exposure of between 24 and 36 hours can be obtained.

## CHEMICALS AND OTHER SUPPLIES.

In the fumigation of mills, warehouses, elevators, and other structures and inclosures infested by insects, especially the Mediterranean flour moth and some other soft-bodied insects, in stored cereals, with hydrocyanic-acid gas two chemicals are used, both poisonous and dangerous to handle. They are cyanid of potassium, called also potassium cyanid and cyanid of potash, of a high grade or chemically pure (98–99 per cent), concentrated sulphuric acid having a specific gravity of about 1.83 or 1.84 (equivalent to 66° Baumé), and water. The standard commercial sulphuric acid will answer.

*Cyanid of potash* (KCN or KCy), the first ingredient, is a white crystalline salt, permanent in dry air, but rapidly decomposable or deliquescent in a moist atmosphere, when it gives off an odor of hydrocyanic or prussic acid. It is readily soluble in water, has a bitter taste, and is extremely poisonous.

*Sulphuric acid* ($H_2SO_4$), the chemical used in liberating the gas, is so well known as scarcely to require description at this point. It might be well, however, to state that it is known commercially also as oil of vitriol or simply "vitriol," and is a dense, oily-looking fluid, colorless when pure, having when concentrated a specific gravity of about 1.8, and containing about 90 per cent $H_2SO_4$. It is nearly twice as heavy as water, and in action it is powerful, being corrosive to both animal and vegetable substances.

*Hydrocyanic acid* (HCN or HCy), the resultant gas liberated by combining cyanid of potash and sulphuric acid, is one of the most energetic poisons known to science. A single drop of the pure acid placed inside of the eye causes instant death. When taken internally it causes paralysis of the heart, of the respiratory center, and of the vasomotor region of the medulla. The immediate cause of death in most cases is due to obstruction of the respiration or to stoppage of the heart's action.

The purity of the cyanid of potash and sulphuric acid to the degree indicated above is essential to the success of fumigation, and efforts should be made to obtain these chemicals through thoroughly reliable firms, and if there is any doubt as to their strength they should be submitted to analysis. Many of the disappointments and failures in fumigation have come from the employment of impure cyanid of potash or acid below the standard strength. These two agents are, however, now in such common use for fumigation purposes that with ordinary care in their purchase there is little risk in this direction.

## PROPORTION OF CHEMICALS.

The hydrocyanic-acid gas is produced by a combination of cyanid of potash and sulphuric acid in water. The most economical and efficient production of the gas, as demonstrated by a recent thorough investigation of the subject by the Bureau of Entomology in cooperation with the Bureau of Chemistry of the Department of Agriculture, is obtained by the following proportions:[a]

| | |
|---|---|
| Cyanid of potash (98 per cent pure), by weight... | 1 ounce avoirdupois. |
| Commercial sulphuric acid, by measure.......... | 1 fluid ounce. |
| Water, by measure.............................. | 3 fluid ounces. |

This formula differs somewhat from some other formulas in use in mill fumigation.[b] Any combination of the three ingredients will produce gas, and hence any one of several formulas which have been recommended and are in use will yield more or less satisfactory results, but the greatest economy in materials with a maximum gas production is secured by following the above proportions. In this formula the acid and water are slightly in excess of the exact chemical needs, but it is essential that all the cyanid shall be converted and that there be sufficient water present to maintain a completely liquid residue. The use of less water, e. g., two parts, may cause a solid residue, due to undissolved potassium sulphate, the by-product resulting from the reaction by which hydrocyanic-acid gas is produced,

[a] See R. S. Woglum, Bul. No. 79, Bur. Ent., U. S. Dept. Agr., p. 33, June 11, 1909.

[b] The formula (1:1:3) above quoted may look quite distinct from older ones which have been in somewhat general use by millers, fumigators, and others, but the difference is very slight and may be explained. The old formula, as originally advised by Johnson (Fumigation Methods, 1902, p. 163), reads substantially that to determine the amount of acid and water one-half more acid (liquid measure) than cyanid and one-half more water than acid are used. "Therefore a room 20 by 30 by 10 feet requires 53 ounces, by weight, of cyanid; 80 ounces, liquid measure, sulphuric acid, and 120 ounces, liquid measure, water." As originally advised by Johnson, the sulphuric acid was liquid measure, but later a more effective formula for fumigating mills and similar inclosures came into use, giving the acid by weight. A formula substantially as follows was substituted with better results:

| | |
|---|---|
| Cyanid of potash (98 per cent pure), by weight.. | 1 ounce avoirdupois. |
| Commercial sulphuric acid (93 per cent pure), by weight................................ | 1½ ounces avoirdupois. |
| Water...................................... | 2¼ fluid ounces or ounces avoirdupois. |

In point of fact, the formula last quoted substitutes the computation of the acid by weight for computation by measure as used in earlier formulas. Thus, while the avoirdupois formula remains nearly the same, owing to the greater atomic weight of the acid, the chemical reaction is almost identical with the formula 1:1:3, which we now advise.

Theoretically the difference in acid between the two formulas is so slight that in fumigating mills the results are about equal. In some cases there might be a slight acid deficiency, resulting in a proportionate deficiency in the amount of gas evolved.

and this solidifying or "freezing" of the residue may prevent complete development of the gas, as has been demonstrated.

Much recent work by experts and agents of this Bureau has demonstrated that for ordinary well-constructed mills or granaries good results may be anticipated by the use of 10 ounces of cyanid of potash and corresponding amounts of the other ingredients to 1,000 cubic feet of air space. This strength, therefore, may be taken as the standard for mill and granary fumigation.

If mills could be made practically air-tight, and some are nearly so, undoubtedly a considerably smaller amount of cyanid to each 1,000 cubic feet would give equally good results,[a] but the miller will hardly be willing to risk success by a slight economy in cyanid and acid, in view of the money loss due to "shut downs" incidental to any fumigation.

In very loosely constructed or more or less open frame buildings, or where only a short exposure is permissible, it is practically impossible to successfully fumigate for most insects affecting stored products; but sometimes, by increasing the amount of cyanid to double the quantity normally employed, fair results may be obtained.

Good results can not be expected with an exposure of less than 16 or 18 hours, while a period of from 24 to 36 hours is preferable.

## ESTIMATING AMOUNTS OF CHEMICALS FOR FUMIGATION OF MILLS.

The first preliminary to the fumigation of a mill or granary is the making of an accurate estimate of the amount of chemicals required for the different stories of the building. It is desirable to make the computation of space for each floor separately and to prepare a table for the guidance of the operators indicating the number of generators and the amount of chemicals to be distributed on each floor. Inside measurements should be taken, and the height of each story should be carefully measured as well as the floor space.

Under ordinary conditions it is best to generate the gas at the standard rate on each floor of the building. The first table which follows illustrates the normal proportions for each floor. These tables are submitted as indications of a convenient method to be followed in making the computations and tabular statement. In view of the fact, however, that the gas is lighter than air and rises, it may be desirable in the case of buildings which have many openings from one floor to another, which can not be easily sealed or stopped up, to develop the greatest amount of gas in the basement,

[a] Mr. C. H. Popenoe, working under the instructions of the writer in the vicinity of the District of Columbia, and Mr. D. K. McMillan, fumigating under the writer's directions in Kansas, have met with success with lower strengths in fumigating nearly air-tight mills and other structures.

and a decreasing amount on each of the succeeding floors, maintaining the total proportion for the building, however, at approximately 10 ounces of cyanid to 1,000 cubic feet of space. An estimate of this kind is illustrated by the second table.

Assuming that the capacity of the upper floor of a given building is 96,000 cubic feet, the minimum amounts of each reagent and water required, according to the same formula, would be:

| | |
|---|---|
| Cyanid of potash | 60 pounds avoirdupois. |
| Sulphuric acid | 60 pints. |
| Water | 180 pints. |

This would necessitate the use of twenty 3-gallon generators and would naturally require the same number of bags which would contain 3 pounds each of the cyanid salt.

While it is essential to success that the cubic contents of each floor be accurately computed, it can be readily seen from the foregoing that many of the details as to the strength must be left to the judgment of the operator, since we have reports of nonsuccess or of only partial success where greater strengths have been used. As frequently happens these reports emanate from distant sources and it has not been possible to give them personal investigation.[a]

Whenever a building can not be so tightly closed as in the case last mentioned—and this matter must necessarily be left to the judgment of the operator—additional quantities are necessary. This is accomplished by employing, for each 1,000 cubic feet, one-fourth to one-half more or even twice the quantity of each ingredient. The amounts to be used for other still more loosely constructed buildings can be calculated in the same manner.

The following tabular statements are submitted as aids in computing the exact proportions for hypothetical buildings of about 1,000 barrels (daily) capacity.[b]

The amounts of chemicals to be used for a given building or other inclosure are in direct proportion to the degree of tightness to which it may be closed. Owing to the great variability of buildings and parts thereof as regards tightness, it follows that no uniform strength can be prescribed.

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[a] As an example, a Wisconsin miller wrote in June, 1909, that, although he had used hydrocyanic-acid gas at the rate of 2 ounces of cyanid to each 100 cubic feet of space (20 ounces to 1,000 cubic feet) for 36 hours, a few individuals seemed to have been missed although everything within reach of the gas was positively killed. This led to the conclusion, in which most millers of experience concur, that the eggs are seldom killed by this or other methods of fumigation now in use. Professor Washburn, however, has succeeded in destroying them, and we fumigated last year (June 6, 1909) a mill product in which there were eggs of this species which later failed to develop.

[b] It should be here stated that millers generally are very apt to take the outside measurements of a building instead of the inside and do not always calculate with sufficient care the height of each floor.

*Tables designating dimensions and cubic contents of each floor and amount of chemicals.*

TEN-OUNCE TABLE.

| Floor. | Dimensions. | Cubic feet. | Cyanid. | Acid. | Water. | Generators. |
|---|---|---|---|---|---|---|
| | | | *Pounds.* | *Pints.* | *Pints.* | |
| Basement | 40 x 60 x 10 | 24,000 | 15 | 15 | 45 | 5 |
| First floor | 40 x 60 x 18 | 43,200 | 27 | 27 | 81 | 9 |
| Second floor | 40 x 60 x 14 | 33,600 | 21 | 21 | 63 | 7 |
| Third floor | 40 x 60 x 12 | 28,800 | 18 | 18 | 54 | 6 |
| Fourth floor | 40 x 60 x 18 | 43,200 | 27 | 27 | 81 | 9 |
| Total[a] | | 172,800 | 108 | 108 | 324 | 36 |

[a] Assuming the cost of cyanid of potash at 25 cents a pound, this would bring the sum for the most expensive chemical to $27. Calculating the sulphuric acid at 3 cents a pound (1 pint = 1.84 pounds) the cost would be $5.96 or $32.96 as the total cost of the chemicals.

*Table for mills with openings in floors.*

| Floor. | Dimensions. | Cubic feet. | Cyanid. | Acid. | Water. | Generators. |
|---|---|---|---|---|---|---|
| Basement | 40 x 60 x 10 | 24,000 | 36 | 36 | 108 | 12 |
| First floor | 40 x 60 x 18 | 43,200 | 36 | 36 | 108 | 12 |
| Second floor | 40 x 60 x 14 | 33,600 | 24 | 24 | 72 | 8 |
| Third floor | 40 x 60 x 12 | 28,800 | 12 | 12 | 36 | 4 |
| Fourth floor | 40 x 60 x 18 | 43,200 | 0 | 0 | 0 | 0 |

This table is intended for use in buildings having large openings, as belt holes, freight elevator shafts, and open stairways in the floors, serving to throw the whole building into one large room.

## PREPARING THE MILL OR OTHER BUILDING FOR FUMIGATION.

After obtaining the chemicals for generating the gas the building should be made as nearly gas-tight as possible, since upon this feature alone depends the amount of chemicals to be used. If the building could be made approximately air-tight, the amount could be materially reduced with consequent saving of expense.

To compass the object desired, every window must be closed as tightly as possible. A good way is to insert plugs of wood on each side of the top of the lower sash and between the "strip." If this does not make the aperture between the two window sashes tight enough, other substances may be used. Cotton batting of good quality is serviceable for inserting into these openings with a case knife, care being taken that it is packed tightly and not loosely. A cheap grade of batting can be used for stopping other apertures. Toweling or rags may be substituted, and after being placed under running water can be dried and reused. Macerated newspapers might serve the purpose, but perhaps the best, because the most secure, remedy for general use consists in pasting paper over the aperture, uncalendered paper of the quality of cheap wall paper or any comparatively porous but not pulpy paper being serviceable. Newspapers are apt to be too soft for this purpose. Cracked panes should be replaced, or paper may be pasted over the apertures.

Similar treatment should be given to the doors and all other natural outlets, including the chimneys, fireplaces, flues, registers, ventilators, cracks in the ceilings and walls, and accidental apertures, such as rat holes in the floor. All of these should be tightly closed.

It is always advisable that at least two persons be present for a last inspection before the final work of liberating the gas. Even after all preparations are made an outlet may sometimes be discovered that has escaped notice.

To provide for quick and thorough ventilation after the process is completed two or more opposite windows should be left unlocked and arranged, especially in the upper floors, so that they may be pulled down or up, as the case may be, by means of a stout cord or rope from the outside.[a]

### CLEANING THE MILL.

As an initial step to the fumigation of a mill or other structure inhabited by the flour moth, it is important to clean it as thoroughly as possible and remove all infested flour or other mill product and promptly burn it, that as many of the caterpillars, pupæ, and eggs of the insect as possible may be destroyed. Most progressive millers employ a system of cleaning out before fumigating, since before the general adoption of fumigation methods in our principal milling centers the only recourse was to close down the mills (which it was found necessary in some cases to do as often as twice a week) and clean out everything by mechanical means. It is feared, however, that too often the sweepings are not properly disposed of by prompt burning.

The operation includes the cleaning of all spouts, elevator legs, purifiers, and other parts of the machinery and other equipment, as also the walls, ceilings, corners—in fact, every portion of the building in which the insect could find lodgment. The reason for cleaning out at this time is to afford the gas a better chance to penetrate all parts of the building so as to kill the insects in their various stages. Every particle of infested flour and waste material which might harbor the insect or its eggs should be swept down and out until the mill appears to be absolutely clean. Then as soon as possible thereafter the preliminaries of the actual fumigation should be undertaken.

*Elevator and belt brush.*—For cleaning elevators infested by the Mediterranean flour moth, Johnson long ago advised a brush similar to the one illustrated (fig. 4). It is made by taking a piece of 1½-inch board of the same dimensions as the elevator cups, fastening the bristles to three sides. Side A is fastened to the elevator belt with flat-

[a] The details of arrangements are considered in Circulars Nos. 37 and 46 of this Bureau, which are for gratuitous distribution.

headed bolts running through the board, as shown at BB, the bolts being ¼-inch or ⅜-inch. The bristles on the sides CC should be ¾-inch long, but those at D should be longer, so that a good brushing to the outer side of the elevator may be secured. Such a brush can be made to fit any size of elevator. As it has been in use for many years and is still advised by the American Miller to correspondents, it is necessarily of value, and something similar should be used in every mill.

*Cleaning by suction.*—For a long time the writer has been endeavoring to ascertain if millers have tried the system of vacuum cleaning advertised in our monthly magazines, and has just received word from one of these companies to the effect that it has only recently taken up flour-mill work. The company, however, is satisfied, beyond any question of a doubt, that their system will clean a flour mill more cheaply than can be done by any other process. Considerable experimental work is being done in some of the principal mills at Minneapolis, and in one of these a plant was installed some time ago. The difficulty in this case is that the steam pressure is not sufficient to work one of the aspirator systems, and this matter is now being investigated with a view to changing the plant to another mill where suitable conditions can be obtained.

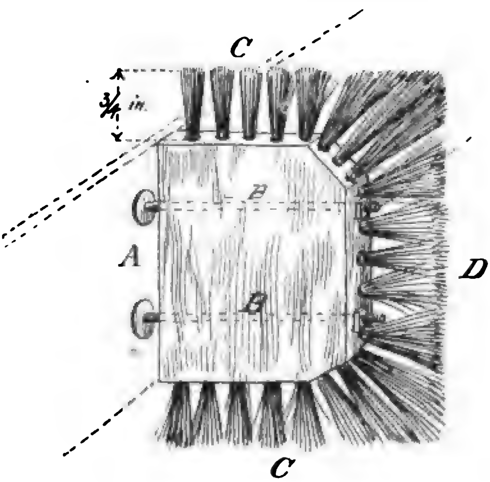

FIG. 4.—Elevator and belt brush, for cleaning elevators infested by the Mediterranean flour moth.

METHOD OF "STRINGING" A BUILDING FOR FUMIGATION.

While the "stringing" method of fumigating mills and other large buildings is scarcely necessary, there are some persons who may wish information in regard to it. The strings are arranged so as to hang directly over each generator, and are carried through screw eyes in the ceiling or woodwork to doors or stairways leading out of the room to be treated. The screw eyes should be firmly secured, and the best quality of cord of the proper size should be employed. The bags containing the cyanid of potash are suspended directly over the vessels, preferably after the acid is added to the water in the

jar, care being taken that there is no danger of their dropping into the generator prematurely. A small wire hook attached to the end of each cord can be used, but if the string is tied firmly around the neck of the sack it causes less trouble and is quite as secure. The cords may be so arranged that the cyanid can all be lowered into the jars by one motion. The entire process is well shown by the accompanying illustration (fig. 5).

A more detailed description of the "stringing" process, by which many bags of cyanid may be lowered into the generators, would require too much space for treatment here. The operator, if he chooses this method, may use his own devices. Pulleys and screw

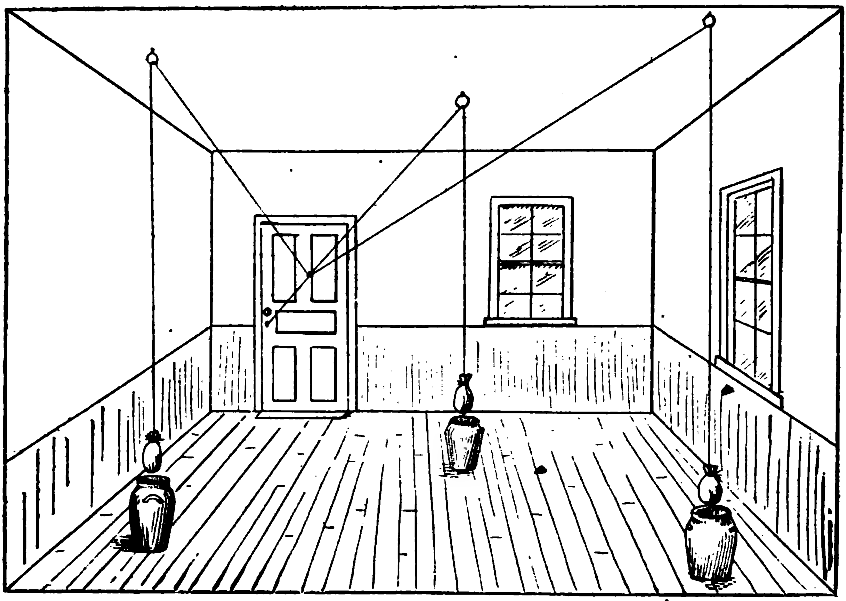

FIG. 5.—Method of stringing a room for fumigating with hydrocyanic-acid gas. (Original.)

eyes are practically necessary in the application of the "stringing" method.

The method is much used in greenhouse work and is desirable for small buildings. This process of "stringing" the building would scarcely be found profitable for mills or dwellings, but in greenhouse work fumigation is frequently done every week or two and often several times a week, and the equipment of screw eyes, pulleys, etc., can remain in place almost indefinitely.

Signs should be placed on the doors of the building that is being fumigated, warning passers-by of the danger, e. g., "Danger!" "Hydrocyanic-acid gas!" "Poison!" The building must, of course, be vacated and neighbors warned of the nature of the operation.

Frequently these precautions are not observed, and although no casualties are on record it is the part of wisdom always to be on the safe side.

PROCESS OF FUMIGATION.

In the process of generating the gas the water is usually measured in a glass beaker indicating ounces, and poured into an earthenware crock or generator. To this is added the acid, measured in the same beaker, which is slowly and gently poured into the water to avoid splashing or boiling. The acid should never be placed in the generators first, as advised by some writers, since experience shows that this is dangerous, spattering being almost certain to follow. When the acid is poured into the water in the jar an ebullition of vapor sometimes arises.

When the cyanid of potash is finally dropped into the combined acid and water mixture an ebullition or bubbling also takes place similar to that which is produced by a red-hot iron dipped into cold water. Next is given off the hydrocyanic-acid gas, the most poisonous gas in common use. It is colorless and has an odor which is likened to that of peach kernels.[a] If the fumes are inhaled they are almost certain to prove fatal; hence the necessity of extreme care and the advisability of two intelligent operators in this work. It is even advisable, especially when the first fumigation is undertaken, that one who has had experience with this method of fumigation be present to give directions. The odor is decidedly metallic, like that produced by striking two pieces of metal together, or of metal against stone.

In preparing cyanid of potash for use it should be broken into lumps about the size of an egg or a little smaller, by pounding it on a stone in the open. The cyanid should never be broken in the hands nor should it be handled without rubber or leather gloves. The smaller fragments, if not too many, are serviceable when equally apportioned as regards large and small particles, and weighed out in 3-pound lots and placed in paper bags or sacks.

The bags should be of moderately thin paper, because if as thin as tissue the action of the acid might be so rapid as to constitute an element of danger. If too thick, action would be delayed or checked, which would militate against the desired results. Before use, the bags should be placed in a can and kept free from moisture, which the cyanid salt is apt to absorb from the air, affording opportunity for leakage through the bag. In some cases, to avoid this leakage, two thin bags, one within the other, might be necessary. Washburn experimented in the use of two sacks with the result that at least 20 seconds elapsed before the gas was evolved.

[a] The writer fails to detect the resemblance.

As soon as all preliminaries have been arranged and the acid has been added to the water in the generators, a bag containing the cyanid should be left at the side of each generator.

After seeing that the generators are placed in rows so as to afford opportunity for rapid action and the acid has been added to the water in each of the jars, begin operations in the upper floor of the building and place the cyanid gently in each jar, passing from one jar to another as quickly as possible and as quickly leaving the room, going downward to the next floor, where the process is repeated until the last floor or basement is reached, where exit is made. The outer doors should be locked and a watchman stationed outside until the process is completed.

This process may be varied if strings or stout cords are used for lowering the bags of cyanid into the jars from the outside, as previously described.

A still day should be selected for fumigation. In case of a high wind the fumes of the gas will escape strongly, which will not alone interfere with the success of the fumigation, but may cause alarm to neighbors should the building not be an isolated one.

Better results are claimed for a warm temperature, say 70° F. or above, than in a temperature as low as 50° F. or below. Under 50° most insects become torpid and the effective action of the chemical will be diminished, especially in very low temperatures.

The best time that could be chosen, and which is generally used where circumstances permit, is during daylight on a Saturday afternoon or very early Sunday morning. This gives a longer exposure than can usually be obtained unless a day preceding a holiday, when all mill hands are on vacation, may be chosen. This permits of a full exposure, as in many cases it removes the necessity of ventilating the building until early the following Monday morning.

A single fumigation will in most cases destroy all but a few individual insects, especially if conditions are favorable. As a rule, however, it is only a matter of a few days or weeks before the moths may be seen beginning to fly about the building or resting on the walls and machinery. To guard against reinfestation, therefore, a second treatment must be given, at the end of the third to the fourth week, according to the number of moths which may have issued in the meantime. If after the expiration of another interval the insects are still present a third fumigation may be necessary. A third treatment is not usually required, however.

Most millers who practice this method of fumigating employ it once a year, some at the intervals above stated, others at intervals of six months. One Michigan miller claims that in his case after one thorough fumigation it is unnecessary to repeat the process until two years have elapsed.

The cans or other receptacles containing the cyanid of potash should be plainly labeled "Poison!" and each operator should become thoroughly familiar with the dangers which may attend a failure to carry out directions explicitly.

### POSSIBLE DANGERS IN USE.

As soon as the bag containing the cyanid is dropped into the generator the operator passes quickly to the next generator, and so on. It is not safe to linger under any circumstances or to return in case of any omission. Any deviation from the set rules may mean the loss of life.

The residue in the fumigating generator after the operation is completed consists of sulphate of potash, sulphuric acid, and water. Sometimes if the chemicals are not of the proper strength or are not properly combined a certain amount of cyanid of potash remains and hydrocyanic-acid gas is given off. This residue is an element of danger and should not be left in the generators after use, but promptly poured or thrown into a sewer trap or buried. The generator should then be thoroughly cleaned in running water.

A question often asked by persons contemplating the employment of the hydrocyanic-acid gas method of treating buildings is as to whether it is dangerous to the contents. It is apt to tarnish, though not permanently, polished brass and nickel when exposed to its action. Where such fittings can be conveniently removed it will save trouble, otherwise they may be treated after fumigation as if tarnished through any other cause. Liquid or moist food materials, such as milk or meats, are apt to absorb the gas and should therefore be removed.

It is not positively known that fires are an element of danger, but persons experienced with this process are united in the opinion that to avoid the possibility of risks all fires, gas jets, and the like should be turned off. There is a possibility of explosion when a gas is generated in a tight inclosure, hence the precaution.

### GENERAL CAUTIONS.

After what has been said of the deadly nature of hydrocyanic-acid gas it should be added that there is really no danger if the directions given in this publication are carefully carried out to the letter and the vapor is not inhaled. Even to taste the salt might have fatal results, and it is dangerous to inhale much gas, as this might cause asphyxiation and death.[a] Undoubtedly thousands of successful fumi-

[a] Scores of entomologists and others, including many employees of the Department of Agriculture, have successfully used this gas for fumigating rooms and buildings. It is in general use as a greenhouse fumigant and for nursery stock and the names of a hundred persons could be mentioned who have had practical experience with it.

gations have been made of inclosures and as yet no fatalities have resulted. Yet it is worth remembering that operators after making numbers of fumigations are apt to become careless, a tendency which should be avoided.

One form of accident should be mentioned, however. If a matting of newspapers or similar material is not placed under each fumigating jar, or if the water is added to the acid, instead of the reverse as advised in this publication, the acid is apt to run over the generator and injure the floor or splash upon the clothing or even the hands of the operator.[a] Such accidents have happened, and to provide against this contingency a bottle of dilute ammonia should be at hand.

If care is observed in labeling the receptacles containing the chemicals, if the operators before using this method become thoroughly conversant with it, and if signs are placed on the doors of the buildings, the chances of accident will be reduced to a minimum if not entirely eliminated. After fumigation buildings should never be entered until at least a half hour (an hour or two is safer) has elapsed after the doors and windows have been opened for ventilation, and under no consideration should an operator return to the place just vacated when the operation is under way.

### SUMMARY OF OPERATIONS AND PRECAUTIONS.

1. Use pure chemicals, generators as prescribed, and paper bags of proper quality.
2. Make every portion of building as nearly gastight as possible.
3. Make first fumigation 10 ounces to 1,000 cubic feet of space, unless building is unusually loose, in which case more must be used.
4. Repeat fumigation at end of three or four weeks if moths begin flying or other evidence of infestation is shown.
5. Measure every portion of building carefully for calculation of the proportions of chemicals.
6. Operators should be intelligent and reliable. Any bookkeeper can readily calculate the cubic contents and proportions of chemicals to use. Careless men should not be employed.
7. Precautions should be made for prompt ventilation from without, after fumigation.

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[a] During July, 1909, a Michigan miller reported that while using 35 crocks as generators, 14 of them boiled over, the contents soiling the floor badly. The explanation in this case was twofold: First, the cyanid was broken into too small lumps, described as about the size of coffee berries, and the floors on which the boiling over was worst were the two upper ones, while no accident happened in the basement. This happened during very warm weather, the top floors being hot while the basement was naturally cool. The miller reported the boiling over as follows: Seven out of 10 on the third floor, 5 out of 10 on the second, 2 out of 9 on the first, none in the basement.

8. Danger signs should be placed in position and a watchman stationed outside until the operation is concluded.

9. Before fumigating clean out the mills thoroughly and provide for the penetration of the gas to every portion by moving bags, boxes, etc.

10. Do not fumigate in a high wind or in a low temperature. Between 65° and 85° F. should produce the best results.

11. Begin operations in the upper floors and pass quickly downward, placing the cyanid gently in each jar.

12. Fumigate preferably on a Saturday afternoon, lock the doors after operations are completed, and expose from twenty-four to thirty-six hours if possible.

13. Never reverse the order of procedure. Always pour in the water first, next the acid, and lastly put in the cyanid in bags.

14. The operator should never return to the building after the first fumes begin to issue.

15. Everyone connected with the fumigation should constantly bear in mind the deadly nature of the cyanid and the gas and be conversant with the process and the necessity of caution before the gas is evolved.

### ORDER OF PROCEDURE IN FUMIGATION.

Briefly, the fumigation of a mill or granary includes the following steps:

1. Measuring the mill and computing the amount of chemicals and number of generators required.
2. Securing the chemicals and the generating jars.
3. Preparation of the mill, including cleaning, sealing up as nearly air-tight as possible, and arrangement for ventilation from without after the conclusion of the fumigation, and preparing signs.
4. Distribution of jars and measuring into each the proper amount of water.
5. Breaking up the cyanid and weighing and placing it in 3-pound lots in sacks, temporarily storing it in tightly covered tin cans, preferably a can for each floor.
6. Measuring out the acid and adding to water in jars.
7. Placing a bag of cyanid in each jar, beginning with the top floor.
8. Tightly closing and locking the building and seeing that all warning signs are in place, and, if necessary, stationing a watchman without to guard the building from entrance.
9. Opening the building from without for ventilation.
10. The collection and disposal, in the sewer or in a pit, of the residue, the cleaning of generators, and sweeping out dead insects and other débris before resuming work.

## EFFECT OF HYDROCYANIC-ACID GAS FUMIGATION ON SEED MATERIAL.

As to the effect of hydrocyanic-acid gas on the germination of seeds, a series of tests was conducted by Dr. C. O. Townsend, now of this Department, when connected with the Maryland state horticultural department, with the resulting conclusion that dry grains and other seeds can be treated with hydrocyanic-acid gas for insect pests at the usual strength and time, or even for several days, without in any way poisoning the grain, from which it was deduced that in the ordinary process this method of fumigation can be employed without injuring seeds either for planting or as food. Damp grains and other seeds, however, are more susceptible to the influence of hydrocyanic-acid gas, and some precaution must be observed in such cases to avoid moisture.

## OTHER REMEDIES.

While the object of the present circular is to furnish information for the fumigation of mills and other buildings by hydrocyanic-acid gas as a remedy for the flour moth, it would be unwise to omit stating that there are several other good remedies, which, however, are not always possible of application.

*Bisulphid of carbon.*—One of these is bisulphid of carbon, especially for small inclosures. It is claimed by some millers to be of value for a first fumigation, following with hydrocyanic-acid gas.[a] When forced into the spouts, machinery, and other portions of the mill, it is a factor in killing the moth and other insects.

*Cleanliness.*—The maintenance of scrupulous cleanliness throughout the mill undoubtedly does much toward preventing the introduction of the flour moth as well as in restraining its increase after it has once obtained a foothold in the mill. Directions for cleaning have been given on page 13. Prominent millers in some of our large cities, e. g., in Louisville, Ky., and in Kansas City, Mo., as elsewhere, have attributed immunity from the flour moth to the fact that they maintain the most rigid system of cleanliness in their mills.

*Sulphur* was used somewhat extensively as a remedy for the flour moth several years before the general employment of hydrocyanic-acid gas, and it is still valuable and in constant use by millers in some States. Lack of space prevents further discussion of this method.

*Freezing* is an inexpensive and valuable remedy where practicable. Where an infested mill can be left open to a temperature of zero or lower, three to ten nights of such exposure continuously or at inter-

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[a] Details in regard to the employment of bisulphid of carbon for fumigating buildings are given in Farmers' Bulletin No. 145, pp. 19–20. Other valuable information regarding this insecticide is also furnished. Copies may be obtained gratis on application to Members of Congress or to the Secretary of Agriculture.

vals will be found effective in destroying the flour moth in its different stages, unless the mill or other building happens to be a heated one. The moths are not apt to breed to any extent during the winter, hence there are few eggs to deal with at this time. In northern mills which have been much affected by this insect, especially in Minnesota and Canada, where the temperature is frequently 20° to 30° F. below zero, this method of destroying the pest has been pursued with most excellent results. Speaking generally, it should be practiced wherever the temperature warrants the process. There are, of course, southern mills, e. g., in Kansas and Texas, where this method would not meet with much success.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *January 22, 1910.*

[Cir. 112]

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CIRCULAR No. 113. Issued November 13, 1909.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE CHINCH BUG.

(*Blissus leucopterus* Say.)

By F. M. WEBSTER,
*In Charge of Cereal and Forage Insect Investigations.*

## INTRODUCTION.

Few insects, and certainly no other species of the natural order to which this one belongs, have caused such enormous pecuniary losses as has the chinch bug (*Blissus leucopterus* Say) (fig. 1). No other insect native to the Western Hemisphere has spread its devastating hordes over a wider area of country (see map, fig. 7) with more fatal effects to the staple grains of North America than has this one. But for the extreme susceptibility of the very young to destruction by drenching rains and to the less, though not insignificant, fatal effect during rainy seasons of the parasitic fungus *Sporotrichum globuliferum* Speg., on both the adults and young, the practice of raising grain year after year on the same areas, as is followed in some parts of the United States, would become altogether unprofitable. Some of this insect's own habits, emphasizing as they do the effects of meteorological conditions, are among the most potent influences that serve to hold it within bounds by giving its tendency to excessive increase a decidedly spasmodic character.

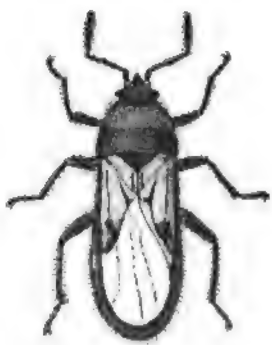

FIG. 1.—Chinch bug (*Blissus leucopterus*): Adult of long-winged form, much enlarged. (Author's illustration.)

DESCRIPTIONS OF THE DIFFERENT STAGES.

*The egg* (fig. 3, *a*, *b*).—The average length of the egg is three one-hundredths of an inch; in shape it is elongate-oval, the diameter being scarcely one-fifth the length. The top is squarely docked and surmounted with four small, rounded tubercles near the center.

FIG. 2.—Chinch bug: Adults of short-winged form, much enlarged. (Author's illustration.)

When newly deposited the egg is pale or whitish and translucent, but with age it acquires an amber color, and finally shows the red parts of the embryo within, and especially the eyes toward the tubercled end. The size increases somewhat after deposition, and the length will sometimes reach nearly four one-hundredths of an inch.

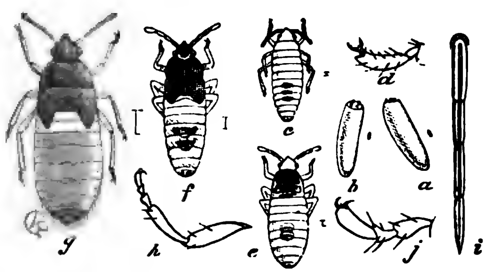



FIG. 3.—Chinch bug: *a*, *b*, Eggs; *c*, newly hatched larva, or nymph; *d*, its tarsus; *e*, larva after first molt; *f*, same after second molt; *g*, last-stage larva; the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same, still more enlarged; *i*, proboscis or beak, enlarged. (From Riley.)

*Larval stages* (fig. 3, *c*, *d*, *e*, *f*).—The newly hatched larva, or nymph, is pale yellow, with simply an orange stain on the middle of the three larger abdominal joints. The form scarcely differs from that of the mature bug, being but slightly more elongate; but the tarsi have only two joints, and the head is relatively broader and more rounded, while the joints of the body are subequal, the prothoracic joint being but slightly longer than any of the rest. The red color soon pervades the whole body, except the first two abdominal joints, which remain yellowish, and the legs and antennæ, which remain pale.

After the first molt the red becomes bright vermilion, contrasting strongly with the pale band across the middle of the body, the prothoracic joint is relatively longer, and the metathoracic shorter. The

head and prothorax are dusky and coriaceous, and two broad marks on mesothorax, two smaller ones on metathorax, two on the fourth and fifth abdominal sutures, and one at tip of abdomen are generally visible, but sometimes obsolete; the third and fourth joints of antennæ are dusky, but the legs are still pale. After the second molt the head and thorax are quite dusky and the abdomen duller red, but the pale transverse band is still distinct; the wing-pads become apparent, the members are more dusky, there is a dark-red shade on the fourth and fifth abdominal joints, and, ventrally, a distinct circular dusky spot, covering the last three joints.

*The last-stage larva* (fig. 3, *g*).—In the last-stage larva, or nymph, sometimes called the "pupa," all the coriaceous parts are brown-black, the wing-pads extend almost across the two pale abdominal joints, which are now more dingy, while the general color of the abdomen is dingy gray; the body above is slightly pubescent, the members are colored as in the mature bug, the three-jointed tarsus is foreshadowed, and the dark horny spots at tip of abdomen, both above and below, are larger.

*The adult.*—There are two forms of the fully developed insect, but it is not known that the young of these two forms differ in any respect. One of these forms is known as the long-winged form and is the only form that occurs over most of the country between the Rocky Mountains and the Allegheny Mountains, and is the one originally described. This form is illustrated in figure 1.

The second form is much like the first, with the exception of the wings, which are more or less abbreviated, as shown in figure 2. This form occurs along the seacoasts and in the East extends inland along the lower lakes to northern Illinois. It is not abundant, however, west of a line drawn from Toledo, Ohio, to Pittsburg, Pa. Throughout the territory in which this short-winged form is found there are also intermingled with them individuals of the long-winged form. Both of these forms may be described as black, with numerous hairs also black, and with the under wings white. The upper wings are whitish, with a black spot on each. They are about one-fifth of an inch or less in length and may be easily recognized by the accompanying illustrations (figs. 1, 2, 3, *h*, *i*, *j*).

## SEASONAL HISTORY.

Over the territory covered by the long-winged form, as previously given, the insect has two generations each year. The young of the first generation appear in May and June, and those of the second generation in August and perhaps as late as September. The adult insects (figs. 1, 2) pass the winter among matted grass, fallen leaves, and other rubbish, and come forth from their hiding in spring and

spread to the grain field, where they deposit their eggs. After the eggs are hatched the old bugs die, and the young hatching from these

FIG. 4.—Corn plant 2 feet tall infested with chinch bugs. (Author's illustration.)

eggs cluster upon the plants and begin at once to live upon the juices. Figure 4 illustrates a corn plant with the chinch bugs clustering upon it. The egg-laying season extends over a considerable period

and chinch bugs of all ages, sizes, and colors are found intermingled. By August the majority of the first generation have reached the adult stage, at which time the eggs are deposited for the second generation, which hatches and matures like the previous one, nearly all individuals reaching their full development by late fall or early winter.

In the eastern portion of the country, where the short-winged form prevails, it is doubtful if there is more than a single generation annually. This short-winged form differs very much in its habits from the long-winged form, the first passing the winter in the meadows, which it usually attacks in preference to grain crops, while with the long-winged form, during the period known as the Indian summer, the developed bugs may be observed flying about, evidently searching for winter quarters. With the short-winged form these migrations to and from the places of hibernation are impossible, the insects being totally incapable of flying because of their short wings. A hint of this characteristic may be witnessed in the case of the exclusively long-winged form, for in migrating from one field to another, even though fully half of the individuals may have fully developed wings, ample for flight, they often travel on foot with the young, even going considerable distances from one field to another.

Throughout the Middle West, then, where this insect does its greatest injury, the crops suffer from two attacks annually, although the later one is seldom noticed. It must be remembered, however, that, although attracting little or no attention, this later attack is of the utmost importance, for, if there are but few of the second generation developing to adults, there can be no serious outbreak the following spring. If, on the other hand, there are enormous numbers of adults developing in the fall and going into winter quarters, there is a probability that, with weather during April and May favorable for their development, there will be an excessive abundance the following year.

It must be remembered that each female of the species is capable of laying from 1 to 500 eggs, and she will scatter them during a period of from two to three weeks. The time required for the eggs to hatch is from about ten days to three weeks, and it requires about forty days for the young to become fully developed after hatching from the egg.

## HIBERNATION.

While the matter of winter quarters has been previously mentioned in a general way, the winter habit of the pest is of such importance that this phase of its life history is deserving of full explanation. Again and again serious and destructive outbreaks of the pest in wheat fields have been traced directly to the influence of shocks of corn fodder allowed to stand in the fields throughout the winter. The chinch bugs which flocked to these corn shocks the previous autumn

were protected throughout the winter, migrating from them in the spring and spreading over the wheat field. In other cases destructive outbreaks have been traced directly to woodlands bordering upon the fields, the chinch bugs beginning their destruction along the margins of the fields nearest to the woodlands, having passed the winter among the fallen leaves. So, too, have destructive outbreaks in the Middle West been traced to the matted grass and fallen leaves bordering hedges of Osage orange (fig. 5). The farmer must understand that it is to such places as these that the chinch bugs flock in the fall, and whatever measures can be effected to prevent their wintering

FIG. 5.—A road between two farms, with neglected hedges on either side affording ample protection for destructive insects during winter. (Author's illustration).

about his fields in this manner will be measures of protection to his crop from attacks of their offspring in the following year.

In the timothy meadows of New England, New York, and northern Ohio these conditions are of less importance, because there the insects pass the winter largely in the meadows themselves, and do not migrate to or from these places, except to travel on foot. Chinch bugs will stand almost any degree of cold, provided it is continuous and they are fairly well protected from sudden changes. Thus it is that the farmer may be able to take advantage of their hibernation to deal a disastrous blow to their occurrence in his fields during late spring and early summer.

## FOOD PLANTS.

Over the western country the major portion of the damage is that accomplished in fields of wheat, barley, rye, and corn, the outbreak generally originating in wheat or barley fields and the bugs migrating at harvest to the cornfields. In the eastern part of the country, where the timothy meadows are the most seriously infested, this is not the case, and here the migrations are as likely to be to the timothy meadows as to the fields of corn where both are equally within reach. Rye and oats are less liable to infestation. The chinch bugs attack sugar cane in Mexico, according to Mr. Albert Koebele. They are known to attack the following grasses: Forked beard-grass (*Andropogon furcatus*), broom beard-grass (*A. scoparius*), oat-grass (*Arrhenatherum*), bur-grass (*Cenchrus tribuloides*), millet, witch grass (*Panicum capillare*), barnyard grass (*Panicum crus-galli*), *Phragmites* sp?, sorghum, kaffir corn, large crab-grass (*Syntherisma sanguinalis*), timothy, yellow foxtail (*Ixophorus glaucus*), green foxtail-grass (*I. viridis*), Bermuda grass (*Capriola dactylon*), and what is locally known in Florida as St. Augustine grass. Prof. Lawrence Bruner has also found it feeding upon so-called buckwheat (*Polygonum dumetorum* or *P. convolvulus*).

It will thus be seen that the insect has an ample food supply outside of the cultivated fields.

## LOSSES CAUSED BY CHINCH BUGS.

It would appear that this pest first made its presence known by its ravages in the wheat fields of the North Carolina farmers, for we are told that "in 1785 the fields in this State were so overrun with them as to threaten a total destruction of the grain. And at length the crops were so destroyed in some districts that farmers were obliged to abandon the sowing of wheat. It was four or five years that they continued so numerous at this time."[a]

In the year 1809, as stated by Mr. J. W. Jefferys,[b] the chinch bug again became destructive in North Carolina to such an extent that in Orange County farmers were obliged to suspend the sowing of wheat for two years. In 1839[c] the pest again became destructive in the Carolinas and in Virginia, where the bugs migrated from the wheat fields at harvest to the corn, and in 1840 there was a similar outbreak, and both wheat and corn were seriously injured. In all of these cases, however, there is no recorded estimate of the actual financial losses resulting from the attacks of the chinch bug. According to Le Baron,

[a] Webster on Pestilence, Vol. I, p. 279. Not seen. Quoted from Fitch.

[b] Albany Cultivator, first series, Vol. VI, p. 201.

[c] The Cultivator, Vol. VI, p. 103.

during the years from 1845 to 1850 the insect ravaged Illinois and portions of Indiana and Wisconsin, and in 1854 and 1855 it again worked serious injury in northern Illinois. The writer's earliest recollection of the chinch bug and its ravages in the grain fields of the settlers on the prairies dates from this last outbreak. Mr. B. D. Walsh estimated the loss to the farmers of Illinois in 1850 at $4,000,000, or $4.70 to every man, woman, and child living in the State.

In 1863, 1864, and 1865 the insect was again destructive in Illinois and other Western States, its ravages being especially severe in 1864, when we have another attempt at computation of the financial loss. Dr. Henry Shimer, of Mount Carroll, Ill., who had carefully studied the chinch bug, estimated that "three-fourths of the wheat and one-half of the corn crop were destroyed by the pest throughout many extensive districts, comprising almost the entire Northwest." In criticizing the doctor regarding another point, Walsh and Riley[a] admit that the estimate was "a reasonable one," and, taking it as a basis, with the actual cash price per bushel, computed the loss at about 30,000,000 bushels of wheat and 138,000,000 bushels of corn, with a total value of both amounting to over $73,000,000. Of course, all computations of this sort are necessarily only approximately correct, but there is more likelihood of an underestimate than of an overestimate in this case.

There was a serious outbreak of the chinch bug in the West in the year 1868, and again in 1871, but in 1874 the ravages were both widespread and enormous. Le Baron computed the loss in 1871 in seven States, viz, Iowa, Missouri, Illinois, Kansas, Nebraska, Wisconsin, and Indiana, at $30,000,000.[b] Riley computed the loss in Missouri alone in the year 1874 at $19,000,000, and added the statement that for the area covered by Le Baron's estimates in 1871 the loss in 1874 might safely be put down as double, or upward of $60,000,000.[c] Dr. Cyrus Thomas, however, estimates the loss to the whole country for the same year at upward of $100,000,000.[d]

The next serious outbreak of the chinch bug of which we have an estimate of the losses occurred in 1887, and covered more or less territory in the States of Kentucky, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, and Kansas. In this case the damage was estimated by the United States statistician, Mr. J. R. Dodge, at $60,000,000, the heaviest losses occurring in Illinois, Iowa, Missouri, and Kansas.[e] This gives us as the estimated loss in the thirty-eight

[a] American Entomologist, Vol. I, p. 197, 1869.

[b] Second Report State Entomologist of Illinois, p. 144.

[c] Seventh Report State Entomologist of Missouri, pp. 24–25.

[d] Bulletin No. 5, U. S. Entomological Commission, p. 7.

[e] Report of U. S. Commissioner of Agriculture for 1887, p. 56.

years from 1850 to 1887, both inclusive, the enormous sum of $267,000,000.

There was a serious outbreak in Kansas, Iowa, Minnesota, and Illinois, having its beginning probably as early as 1892, but reaching its maximum severity, as in Ohio, in 1896. The loss in Ohio during the years 1894, 1895, 1896, and 1897 could not have fallen far short of $2,000,000. If we could have careful estimates of the loss during the last fifteen years it would in all probability swell the amount to considerably in excess of $350,000,000 for the period from 1850 to 1909. (See map, fig. 6.)

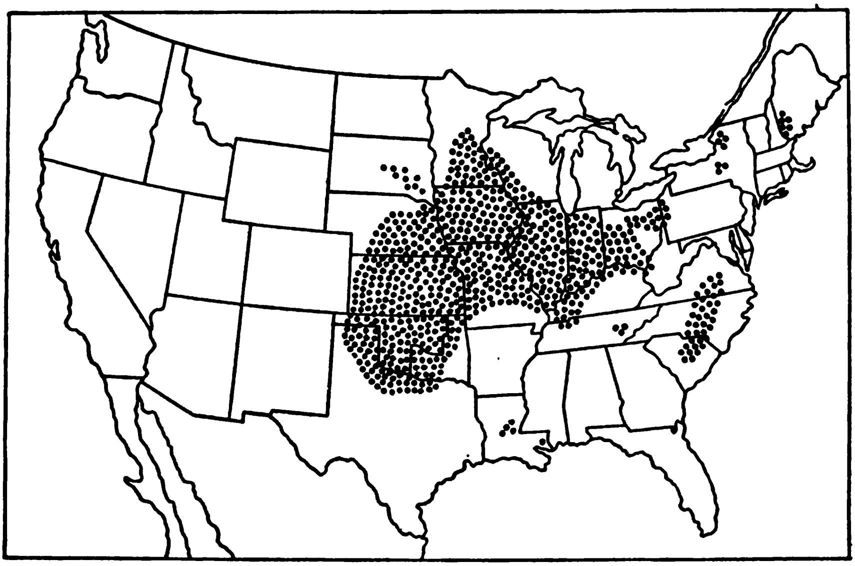

FIG. 6.—Areas in the United States over which the chinch bug occurs in most destructive numbers. (Author's illustration.)

## NATURAL ENEMIES OF THE CHINCH BUG.

Chinch bugs have few natural enemies, none of which, owing, perhaps, to their repugnant odor, appears to be of any very great importance when it comes to suppressing a serious invasion. They are far more fortunate than most insects in escaping the attacks of natural enemies that exert a tremendous influence in holding other species in check.

### THE BOBWHITE OR QUAIL.

Inland, the common "quail" or bobwhite (*Colinus virginianus*) is the only bird that can be said to devour the chinch bug in considerable numbers. It is said that from 300 to 400 chinch bugs have been found in the crops of bobwhites; 100, however, is the largest number found so far by the Biological Survey. As the bobwhite is one of

our most highly prized game birds, it is slaughtered annually in tremendous numbers, frequently with no other object in view excepting for gain. Some also are killed by flying against electric wires, while during severe winters entire coveys are sometimes smothered or frozen under the snow. As a result, the helpfulness of the quail against chinch bugs is greatly diminished. It would seem that as important an enemy of the chinch bug as this bird is known to be would receive protective immunity throughout the agricultural regions and that farmers would see to it that protective laws were not only enacted but also stringently enforced.

The following list will show the degree of protection offered the quail by legislative enactment in the States where the chinch bug is the most destructive (see map, fig. 6). The close seasons for quail in the several States, during which killing is prohibited by law, are as follows:[a]

Maine, all the year.

New York, December 1 to November 1, except in Dutchess, Putnam, Richmond, Rockland, and Westchester counties, where it is closed until 1910.

Pennsylvania, November 15 to October 15.

Ohio, December 5 to November 15.

Indiana, January 1 to November 10.

Illinois, December 10 to November 11.

Minnesota, December 1 to October 1.

Iowa, December 15 to November 1.

Missouri, January 1 to November 1.

Nebraska, all the year.

Kansas, December 15 to November 15.

Oklahoma, February 1 to November 15.

Texas, February 1 to November 1.

The breeding season from latitude 38° northward to Canada begins in May and continues through July and occasionally into September.

## OTHER BIRD ENEMIES.

To what extent the birds of the coast region feed upon the chinch bug it is impossible to say. However, among the bird enemies of the pest are the prairie chicken, redwing blackbird, catbird, brown thrush or thrasher, meadowlark, house wren, tree swallow, horned lark, Arkansas kingbird, Traill flycatcher, seaside sparrow, savanna sparrow, song sparrow, tree sparrow, and barn swallow.

## THE FROG.

Dr. Cyrus Thomas quotes Ross and others as stating that the common frog is an enemy of the chinch bug. While this is probably true, it is nevertheless well known that comparatively few frogs frequent grain fields, as a rule, and thus the benefit derived from their attacks is of too little importance to merit further notice.

[a] From Farmers' Bulletin No. 376, pp. 18–29, 1909.

## INSECT ENEMIES.

Of the invertebrate enemies of the chinch bug the same may be said as of the frog. The writer has occasionally found a chinch bug containing a species of Mermis, or "hair snake." Occasionally, also, ants may be seen dragging these bugs away, while lady-beetles have sometimes been found to devour them, as recorded by Walsh and Forbes. Perhaps the worst insect enemies of the chinch bug are to be found among its comparatively near relatives—the insidious flower bug (*Triphleps insidiosus* Say), (*Anthocoris pseudo-chinche* of Fitch's Second Report), and *Milyas cinctus* Fab., the latter being reported by Thomas as the most efficient of the insect enemies of this pest, while Riley found that the former also attacked it. Professor Forbes ascertained, by examinations of the contents of the stomach of a ground beetle (*Agonoderus pallipes* Fab.), that one-fifth of the total food of this species was composed of chinch bugs. Shimer and Walsh both claim that lacewing flies (*Chrysopa* spp.) destroy chinch bugs, and they are doubtless correct. The writer has also very often found dead chinch bugs entangled in spider webs, although whether killed for food or by accident it has been impossible to determine.

## NATURAL CHECKS OTHER THAN ANIMALS.

There are two natural checks to the increase of the chinch bug other than animal enemies. One of these is vegetable in nature, being a fungus, the other meteorological, and the interrelation of the two is so close that the former is almost entirely dependent upon the latter. It will at once be seen that the chinch bug, occurring, as it does, from but little north of the equator to nearly a latitude of 50° north and from an elevation of upward of 200 feet above the sea level in the Imperial Valley of southern California to an elevation of upward of 6,000 feet in the mountain regions, must be able to withstand almost every conceivable variation of climatic conditions. (See map, fig. 7.) So far as the influence of temperature is concerned, it is only in the most unprotected situations that severe winter weather appears to have much effect in regulating the abundance of the pest, although frequent freezing and thawing is known to be fatal to a large percentage of the adults if these occur in exposed situations. Thus temperature may practically be eliminated from consideration. It is also true that the nearly developed insect will withstand not only the humidity of the Tropics, but continuous drenching rains of more northern latitudes. It is at the time of hatching that the species is most susceptible to meteorological conditions. Frequent drenching rains during the hatching season are fatal to the pest almost to the extent of extermination, and it is due

to this more than to any other influence that the chinch bug is kept within the limits of its present abundance and destructiveness. It matters little how great a number of these insects pass the winter in safety, provided there are sufficiently prolonged, drenching rains

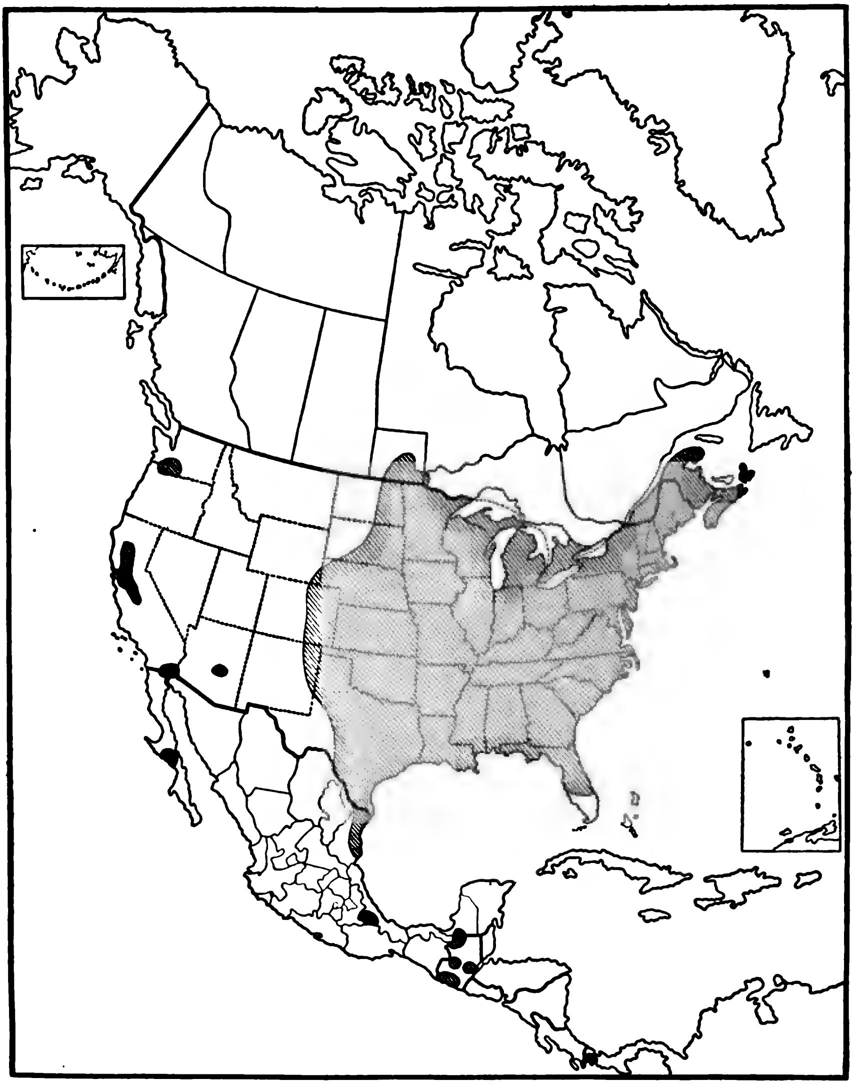

FIG. 7.—Map of North America showing areas infested by chinch bug. (Author's illustration.)

during the hatching period. Again, with an excessive abundance of individuals developing from the first generation, if at the time of the hatching of the young of the second generation there are frequent drenching rains, an outbreak the following year is prevented. Thus it is that although an outbreak may seem inevitable as the

season for the ravages of the chinch bug draws near, there is often a radical reduction instead of an increase in numbers. The forecasting of chinch-bug outbreaks is therefore based wholly upon the forecasting, months in advance, of meteorological conditions that are likely to occur at certain periods. If the farmer would but watch the seasons, he need not be taken unawares by chinch-bug outbreaks, as dry weather during the two breeding seasons is usually sufficient to precipitate an invasion the following year, provided that, at the critical period or time of hatching, rains do not destroy the young. The general statement may be made that throughout the Middle West a dry June followed by a dry August is favorable for the development of chinch bugs. These dates will of course vary, and must not be applied to the more southern or more northern localities.

### PARASITIC FUNGI.

The fact that the abundance and consequent influence of fungous enemies of the chinch bug are almost entirely dependent upon meteorological conditions is sufficient to place them in a secondary position, even though they may, under favorable weather conditions, act as natural checks.

Dr. Henry Shimer[a] long ago made the truthful and important statement that "this disease among the chinch bugs was associated with the long-continued wet, cloudy, cool weather that prevailed during a greater portion of the period of their development." These are precisely the conditions under which these fungi have been observed to prove the most fatal to the chinch bug during recent years where their introduction among the host insects was accomplished by artificial means. Although Shimer probably never anticipated the artificial cultivation of his "disease" and the results which have since been obtained from its artificial dissemination in the fields, yet his careful and painstaking studies must ever be associated with the application of fungous diseases in the destruction of insects in America.

The principal fungus to be artificially employed in destroying chinch bugs has come to be known as the chinch-bug fungus (*Sporotrichum globuliferum* Speg.), and this is the one used by Doctor Snow in Kansas for artificial introduction into localities where there is an overabundance of these bugs.

Doctors Roland Thaxter and S. A. Forbes devised a method of artificial cultivation, the latter using a basis of sterilized mixture of beef broth and corn meal. As this fungus has many other host insects, it is probably present to a greater or less degree throughout the country every year. There is no doubt that during wet weather

[a] Proc. Acad. Nat. Sci. Phila., May, 1867.

considerable benefit may be derived from the artificial cultivation and application of this fungus, but its efficiency is very dependent upon this meterological condition, and, as has already been shown, chinch bugs develop in the greatest abundance in dry seasons. It will thus be seen that only during unusual seasons—that is to say, seasons that have been dry while the chinch bugs were hatching from the eggs but wet afterwards—can satisfactory results be expected from this measure.

The effects of this fungus have probably been overestimated, although there is no doubt whatever that those who have been most instrumental in popularizing this means of destroying chinch bugs were thoroughly sincere and honest in their statements. One very important element of deception to the ordinary farmer, when assuming the results of the effect of this fungus, lies in the fact that chinch bugs, when molting for the last time and passing from the last-stage larva to the adult, hide away under the sheaths of corn and other grain, and, casting the larval skin, make their escape, leaving this behind. These cast skins will occur in immense numbers in such places and frequently become covered with a white mold. It is almost impossible for anyone except an expert to distinguish the difference between chinch bugs that have been actually killed by this fungus and the mass of cast skins covered with ordinary mold. The uncertainty as to the effects of this fungus is responsible for its having fallen largely into disuse during recent years. It will thus be seen that this whole matter hinges upon meteorological conditions which are, as has been stated, most powerful factors in holding the chinch bug continually in check, and it is following a succession of dry seasons that the pest commences to become destructive. During seasons of excessive abundance of chinch bugs, this fungus will almost invariably appear among them in the fields, provided that at this time there occurs a considerable period of wet weather.

## REMEDIAL AND PREVENTIVE MEASURES.

All remedial and preventive measures that have been found to possess the merit of reasonable efficiency and practicability are discussed in the following pages. These may not all prove applicable in all localities or under every variety of circumstance, and the farmer will often have to adapt his protective measures to weather conditions, location of field and its surroundings, and to the thousand and one other variations of a similar nature.

### DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The first effort that may be made with a view to warding off an attack of chinch bugs is to destroy them in their winter quarters.

This can be accomplished by burning all dried grass, leaves, or other rubbish during winter or early spring. The burning of all such grass will destroy thousands of bugs in their winter quarters; but sometimes the matted bluegrass remains green in winter, or the weather is not sufficiently dry to enable the farmer to burn over such places. In such cases a flock of sheep, if given the freedom of the fields during winter and spring, will eat off all living vegetation and trample the ground with their small feet, so that not only is all covering for the bugs removed, but also the bugs are crushed to death. So it is with the matted grass along roadsides and fences,

FIG. 8.—Poorly kept roadside with rail fence overgrown with brambles, thus affording protection for large numbers of destructive insects during winter. (Author's illustration.)

especially the Virginia worm rail fence (fig. 8). The ease with which the narrow strip of grass land along a post-and-wire fence can be kept free of matted grass and leaves, as compared with that along a hedge or rail fence, indicates that there may be an entomological factor connected with the modern fence that has been overlooked, giving it, in this respect, an advantage over the more ancient form. A good illustration of the fact that large numbers of chinch bugs may be in hiding among fallen leaves in woods and other places and escape detection is shown by the fact that a quantity of dried leaves from about a vineyard located on a narrow neck of land about a quarter of a mile from the Bay of Sandusky on the one side, and about 1½

miles from the shore of Lake Erie on the opposite side, was collected late in April. At the time of collecting the leaves only an occasional chinch bug was to be observed, but under a warm atmosphere they began to bestir themselves, and soon demonstrated that there had been a large number ensconced unseen among the dried and curled, dead grape leaves.

Shocks of fodder corn, left in the fields over winter, certainly afford protection for many chinch bugs, as will also coarse stable manure spread on the fields before the chinch bugs have selected their place of hibernation in the fall. In short, the first protective measure to be carried out is a general cleaning up in winter or early spring either by burning, or pasturing, or both.

### SOWING DECOY PLATS OF ATTRACTIVE GRAINS OR GRASSES IN EARLY SPRING.

Judging from the manner in which the overwintered adults are attracted to hills of young corn, wheat fields, or plats of panic and foxtail grasses, it has always seemed to the writer practicable to take advantage of this habit and sow small patches of millet, Hungarian grass, spring wheat, or even corn, early in the spring and thus bait the adults as they come forth from their places of hibernation. Their instincts will prompt them to seek out the places likely to afford the most desirable food supply for their progeny, and, if an artificial supply can be offered them that will be more attractive than that furnished by nature, the bugs will certainly not overlook the fact, but will take advantage of it to congregate and deposit their eggs there, whereupon eggs, young, and adults can, a little later, be summarily dealt with by plowing both bugs and their food under and harrowing and rolling the ground to keep the former from crawling to the surface and escaping. The writer has thoroughly tested this method in a case where the bugs, young and old, had taken possession of a plat of neglected ground overrun with panic grass (*Panicum crus-galli*), which was mown and promptly removed and the ground plowed, harrowed, and rolled before the bugs could escape, thus burying them beneath several inches of soil, out of which they were unable to make their way. As a consequence they were almost totally annihilated, hardly 1 per cent making their escape to an adjoining cornfield.

### WATCHFULNESS DURING PROTRACTED PERIODS OF DROUGHT.

It has always appeared to the writer as though a little watchfulness on the part of farmers during periods of drought might enable them to determine whether or not chinch bugs were present in any considerable numbers in their fields in time to interpose a strip of millet between the wheat and corn, to be utilized later as previously indi-

cated. Instances have come under observation where, in wheat fields overgrown with panic grass and meadow foxtail, the bugs transferred their attention to these grasses as soon as the wheat was harvested. In such cases a prompt plowing of the ground would have placed the depredators beyond the possibility of doing any serious injury. If the weather at the time is hot and dry, a mower may be run over the stubble fields or along the borders of them, cutting off grass, weeds, and stubble, as the case may be, leaving them to dry in the hot sun, when, in a few hours, they will burn sufficiently to roast all bugs among them, and, while not destroying every individual, this will reduce their numbers to such an extent that they will be unable to work any serious injury.

### DIFFICULTY OF REACHING CHINCH BUGS IN MEADOWS.

There is, however, some doubt in regard to the practicability of applying these measures in timothy meadows. Meadow lands can be burned over with perfect safety to either the grass or clover, if done while the ground is frozen, but there is danger of injury if burned over in spring, and it is somewhat doubtful if the hibernating chinch bugs would be killed unless the surface of the ground was heated to a degree that the grass and clover plants would hardly be able to withstand.

Infested areas of meadow land could be plowed, it is true; but the work would have to be done very carefully, else the grass and stubble would be left to protrude above ground along each furrow and constitute so many ladders by which the chinch bugs could easily crawl out and make their escape. Where the ground will admit of subsoiling, or where a "jointer" plow can be used, this latter difficulty can be easily overcome. Usually, however, the chinch bugs work too irregularly in a field to permit of plowing under infested areas without disfiguring the field too much for practical purposes, especially in the case of meadows, unless it be where the bugs have migrated en masse from an adjoining field, when a narrow strip along the border can often be sacrificed to good advantage. In many instances the drastic measure of turning under a few outer rows of corn with the plow would have saved as many acres from destruction. In the majority of cases it is the fault of the farmer himself that these measures are not effective, as he will seldom take the trouble to burn the dead leaves, grass, and trash about his premises at the proper time, and when there occurs an invasion of chinch bugs, instead of resorting to heroic and energetic measures to conquer them on a small area, he usually hesitates and delays in order to determine whether or not the attack is to be a serious one, and by the time he has decided which it is to be the matter has gone too far, and the chinch bugs have taken possession

of his field. This is especially true in the West, where the bugs breed exclusively in the fields of wheat and remain unobserved until harvest, when they suddenly and without warning precipitate themselves upon the growing corn in adjacent fields. In fighting the chinch bug promptness of action is about as necessary as it is in fighting fire.

### ELIMINATING CHINCH BUGS FROM TIMOTHY MEADOWS BY CROP ROTATION.

In several instances where chinch bugs have become especially destructive to timothy meadows over considerable areas of country, it has been found that these outbreaks were attributable to the fact that these sections of country were largely given over to dairying. The dairymen and stockmen found it more desirable to allow timothy pastures and meadows to remain more or less permanent, with the result that the chinch bugs gradually became so excessively abundant as to destroy the grasses on these areas. In a number of instances it was found that where the prevailing agricultural methods were changed and the infested grass lands were broken up and devoted to other crops, the difficulty was eliminated, as the new meadows were not attacked. This shows that throughout the country where the short-winged chinch bug attacks timothy meadows a rotation crop will be found an efficient measure in overcoming the difficulty with a reasonable degree of permanency.

### UTILITY OF KEROSENE IN FIGHTING CHINCH BUGS.

In fighting the chinch bug there is at present no more useful substance than kerosene, either in the form of an emulsion or undiluted. From its penetrating nature, prompt action, and fatal effects on the chinch bug, even when applied as an emulsion, it becomes an inexpensive insecticide, while it has the further advantage of being an article universally found in every farmhouse, and is therefore always at hand for immediate use. The emulsion has the further advantage of being capable of sufficient reduction in strength to preclude injury to the vegetation while still strong enough to be fatal to insect life. Diluted and ready for use, the emulsion is prepared as follows: Dissolve one-half pound of hard soap in 1 gallon of water, preferably rain water, heated to the boiling point over a brisk fire, and pour this suds while still hot into 2 gallons of kerosene. Churn or otherwise agitate this mixture for a few minutes until it becomes of a creamlike consistency and, on cooling, forms a jellylike mass which adheres to the surface of glass without oiliness. For each gallon of this emulsion use 15 gallons of water, mixing thoroughly. If applied to growing corn, it will be best to use the emulsion either during the morning or evening, say before 8 a. m. or after 5 p. m., as at these times it will be less likely to affect the plants than if applied in the heat of the day.

Where an invasion of the chinch bug is in progress from a field of wheat to an adjoining field of corn, as an illustration, the marginal rows of corn can be frequently saved, even after the bugs have massed upon the plants, by spraying or sprinkling them freely with kerosene emulsion, being careful not to get much of it directly into the crown of the plants and using a sufficient quantity so that the emulsion will run down the outside and reach such bugs as are about the base of the plants. This treatment will kill the bugs clustered upon the corn, and in case of those on the way to the field, while it will not keep them out, it will cause a halt in the invasion, and thus give the farmer an opportunity to put other measures in operation, one of which will include the use of kerosene in another manner. If a deep furrow is plowed along the edge of the field, running the land side of the plow toward the field to be protected, the furrow will form a temporary barrier to the incoming hordes.

### UTILITY OF DEEPLY PLOWED FURROWS SUPPLEMENTED BY THE USE OF KEROSENE EMULSION.

In dry weather the sides of the furrow can be made so steep and the soil so finely pulverized that when the chinch bugs attempt to crawl up out of the furrow they will continually roll back to the bottom, where they can be sprinkled with either kerosene alone or with the much less expensive emulsion and killed. In case of showery weather, which prevents the sides of the furrow from remaining loose and dry, the bottom can be cleared out with a shovel, making it more smooth and the sides more perpendicular, thus rendering it so much easier for the bugs to follow along the bottom than to attempt to climb the sides. If holes are dug across the bottom at distances of, say, 30 or 40 feet, the bugs will fall into them and can be still more easily disposed of by the use of kerosene. That both of these measures are thoroughly practicable the writer can attest by ample personal experience, and he knows that under most conditions that are likely to obtain prompt and efficient application is all that is necessary. During a few days this work will demand the closest watching and application, but fields of grain can be protected thoroughly and effectually if these measures are faithfully carried out, and the expense of time and money will be found to be less than in almost any other plan that has been discovered up to this time. In no case has a field attacked by a migrating army of chinch bugs come under the writer's observation but that might have been saved from very serious injury by the prompt use of either of these measures, though under some conditions the farmer might find it advantageous to apply some of the other methods of protection here given. In all of the following methods crude petroleum may be substituted for coal tar if the former is more easily obtainable.

### THE SURFACE AND COAL-TAR METHOD.

The objections made by farmers to the use of most of these barriers is that the finest pulverized soil soon becomes incrusted by even the slightest rainfall and the bugs then pass over it without difficulty, while barriers of boards are expensive. It is feasible to eliminate both by simply smoothing off a path along the margin of an infested field where such an one adjoins the one to be protected. This can be done with a sharp hoe, and as the margins of wheat fields usually become compacted, it is but little trouble to thus clear off a path a foot or more in width, smooth as a floor, with the surface almost as hard. Along this path circular post holes are sunk, as in the bottom of furrows, and a train of coal tar is run between them, being so arranged that it will reach the post hole at the edge farthest from the field from which the bugs are migrating. The bugs, on reaching the train of coal tar, will follow along until they reach the post hole, while those meeting with the post hole will usually divide and, following around it, join with the flow of bugs moving along the train of coal tar. The result is that they become congested in the acute angle where the coal-tar train is intercepted by the post holes. Those in the apex of this angle can not turn back, and thus are continually pushed into the post holes by those behind. As the bugs, varying from the red larvæ of the younger stages to the almost black ones of the last stage, mass along the line of coal tar, they have much the appearance of a reddish-brown stream running into the holes. From these holes there is no escape and here the bugs can readily be killed by sprinkling with kerosene. The slightest train of coal tar is sufficient to obstruct the passage of the bugs, and light rains will not affect its efficiency. In dry weather these trains of coal tar soon become covered over with dust and must be renewed; but in showery weather there is no dust, and if the coal tar is renewed daily or, at most, twice each day, it will accomplish its work and nothing further will be needed than to kill the bugs that have collected in the post holes. This measure is inexpensive and can be promptly put into operation if the coal tar is at hand. The writer has been able in this way to effectively protect a field of corn bordered on two sides by a wheat field literally overrun with chinch bugs at harvest and during a time when light showers were occurring, frequently several times each day.

### THE RIDGE AND COAL-TAR METHOD.

Differing quite materially from the preceding are the various combinations of coal tar and ridges of earth, smoothed and packed along the apex, or, instead of the ridge of earth, 6-inch boards, such as are ordinarily used for fencing, placed on edge and the upper edge coated

with tar. Forbes has reported excellent results from the application of a line of coal tar put directly upon the bare ground where the surface has been rendered compact by a recent fall of rain. Even in this series of protective measures kerosene can be used to great advantage. In the experiment recorded by Professor Forbes the coal tar was put upon the ground between a wheat field and a cornfield from an ordinary garden sprinkling pot from which the sprinkler had been removed and the orifice of the spout reduced in size with a plug of wood until the tar came out in a stream about the size of the little finger and made a line on the surface of the ground about three-fourths of an inch in width. Post holes were sunk along the line from 10 to 20 feet apart on the side next to the wheat field, thus practically completing the barrier, and the chinch bugs, being unable to cross the line of tar, accumulated in the post holes in vast numbers, where they were killed, and those bugs that had already entered the cornfield before the barrier was constructed were prevented from spreading farther by tar lines between the rows of corn, the infested corn itself being cleared of bugs by the application of kerosene emulsion. The same writer states[a] that several farmers in Vermilion County, Ill., prepared for the coal-tar line by hitching a team to a heavy plank and running this, weighted down with three or four men, over the ground once or twice until a smooth, hard surface had thus been made to receive the tar. If the barrier was to be made in sod, a furrow was plowed and the bottom of this made smooth by dragging the plank along the bottom. In both cases post holes were sunk along the tar lines, and in these were placed cans or jars into which the bugs fell in myriads and were destroyed.

On one farm of 250 acres a coal-tar line 90 rods in length was renewed once each day and killed about 8 gallons of chinch bugs. In the case of another farmer there were 300 rods of tar lines with post holes, cans, etc., which resulted in destroying about 10 bushels of chinch bugs. A 6-gallon jarful was destroyed in less than half a day at one point on the line. In this last instance the lines of tar were renewed three times a day, but even then less than a barrel of tar was used. Still another farmer, with 120 rods of tar line, used about a third of a barrel of tar and did not lose a hill of corn; he caught chinch bugs by the bushel. In some of the cases cited the tar line was run in a zigzag course, the post holes being situated at the angles, and in others leader tar lines were run obliquely to the main tar line, one end terminating at the traphole, but both of these plans were afterwards regarded as unnecessary, a single straight line being entirely sufficient and less expensive. The numerous cases where these methods were put into execution with entire success and

[a] Twentieth Report State Entomologist of Illinois, p. 39, 1898.

at small expense afford the best possible proof of their practical utility. If a farmer is situated near town, where refuse tin cans are dumped in any locality where they can be got out of the way, he can select the larger of these, set them in the post holes and partly fill them with kerosene and water. The water, being heavier than the kerosene, will sink to the bottom, leaving a stratum of kerosene on the surface. The chinch bugs falling into this will be forced down by the weight of those coming after, and thus all will be passed through the kerosene into the water below. This will obviate the necessity of frequently emptying the cans or treating their contents. It may also be stated that where the post holes are quite deep and enlarged at the bottom the bugs falling into them will perish without further attention.

### OTHER BARRIER METHODS.

The late Professor Snow, working in Kansas, followed a somewhat different method, and one that, under certain conditions, might be found superior to that used by Professor Forbes, or the furrow and kerosene method applied by the writer in Ohio. This modification consists in throwing up a double furrow, known among farmers as "back furrowing," and thus forming a ridge, the top of which is smoothed and packed with a drag having a concave bottom of the form of the ridge to be made. If the bottom of this drag is covered with zinc, it will be found to keep bright and polished, and by this means make a smoother ridge. Along the top of this ridge is run a train of coal tar as it came from the gas works, or crude petroleum as taken from the oil wells. The former is more easily obtained, except in certain localities, and will probably be found the more practical, as it stands on the surface better and is not so readily washed away by rains. Both of these substances are, however, offensive to the bugs, and they will seldom attempt to cross them or even come close enough to touch them, but on approaching will turn and run along the ridge in the evident hope of finding a gap through which they can pass. Post holes were dug on the outside of the line, but close up to it, so that the bugs in passing along beside the tar line would crowd each other into them. Professor Snow suggested that it will be better to construct this barrier several weeks prior to the time when it will be needed, as then the tar line has but to be run along the ridge, and the post holes dug, when the whole system is complete, and the chinch bugs can be thus shut out from the first.[a]

With these barriers of either ridge or furrow and the use of coal tar or crude petroleum, supplemented by kerosene emulsion, a very large percentage of the injury from chinch bugs may be obviated,

[a] Fifth Annual Report of the Director of the Experimental Station of the University of Kansas, for the year 1895 (1896), pp. 45–47.

and, in fact, with a reasonable degree of watchfulness and prompt action, all injury from migrating hordes may be prevented. The use of tarred boards set on edge or slightly reclining might, under some circumstances, take the place of the ridge or furrow, but these cases will be exceptional, and the use of kerosene emulsion will probably be found equally practicable here, as also will the post holes for collecting the chinch bugs. This method is merely cited in order to call attention to its possible use where the others are found impracticable.

### THE USE OF FURROWS WITHOUT PETROLEUM OR COAL TAR.

The plowing of furrows has been in vogue since the first writings of Le Baron and the second report of Fitch, and may be utilized in other ways than those previously mentioned. A heavy log dragged back and forth in this furrow will pulverize the soil in dry weather, and Doctor Forbes has recorded the fact that where this furrow has a temperature of 110° to 116° F. it is fatal to the young bugs that fall into the furrow, even if they are not killed by the log. As 120° is not uncommon in an exposed furrow on a hot summer day, it will be observed that there may be cases where this method will be found very serviceable, and especially is this likely to prove true in a sandy soil with a southern exposure. In sections of the country where irrigation is practiced, these furrows may be flooded and in this way rendered still more effective without the expenditure of either time or money to keep them in constant repair. Riley long ago laid considerable stress on this measure, believing it of much value, especially in the arid regions of the far West. The same writer advised the flooding of infested fields, wherever it could be done, for a day or so occasionally during the month of May. It is hardly probable, however, that this will often be found feasible except in rice fields, where it is sometimes practiced.

### NECESSITY FOR PREVENTING CHINCH BUGS FROM BECOMING ESTABLISHED IN FIELDS OF WHEAT AND GRASS.

In the foregoing it will be observed that prevention of migration has been the chief end in view, either by destroying the chinch bugs in their hibernating quarters, and thus preventing the spring migration to the breeding places, or by various traps and obstructions to prevent them from migrating from such places to others not already infested. The great problem remaining to be solved is to prevent their breeding in wheat fields at all. As has been shown, it is absolutely impossible, with our present inability to forecast the weather months in advance, to be able to foretell whether or not an outbreak of chinch bugs is likely to take place. There may be an abundance of bugs in the fall—enough to cause an outbreak over a wide section of country—and these may overwinter in sufficient numbers to cause some injury

in spring, yet a few timely, drenching rains will outbalance all of these factors, and our wisest prognostications fail of proving true. It is this very factor of uncertainty that renders unlikely the successful carrying out, over any large area of country, of any protective measures, where, as in this case, the benefit to be derived will only be realized nearly a year afterwards, if at all. The average farmer, when smarting under a heavy loss, will often take such long-range precautions as to sow belts of flax, hemp, clover, or buckwheat around his wheat fields once; but if the chinch bugs do not appear, and he sees the useless investment of time, labor, and seed, he will be likely to conclude next year to take the risk and do nothing. For the present, then, we have no method whereby we can prevent the chinch bugs from taking up their abode in wheat fields or timothy meadows and raising their enormous families there, except to destroy the adults in their winter quarters.

The writer once tried to destroy the young in a wheat field by spraying with kerosene emulsion the small areas of whitening grain that indicated where the pests were massed in greatest abundance. The result was unsatisfactory, and it is very doubtful if it is possible to apply this measure with any degree of success, and we are forced to the conclusion that, for the present at least, we shall be obliged to rely upon the measures previously given. It therefore becomes of the utmost importance to clean up the roadsides, and the ground along fences and patches of woodland, as well as any other places likely to afford protection for the hibernating chinch bugs. There are, of course, obstacles in the way of carrying out this plan generally over any large area of country, and especially in sections where the rail fence predominates. But as the country gets older it will be found that it is not chinch bugs alone that seek these places in which to pass the winter, but myriads of the other insect foes of the farmer as well, and that careful attention to the condition of roadsides, lanes, hedgerows, and waste places about the farms, during the season when insects seek out these places wherein to pass the winter, will pay well for the time expended in that direction. It may come about that some phase of the street-cleaning reform may invade the country, and it is certain that if such were to occur it would, in time, save the country enough to go far toward reducing the expense of securing good roads. In fact, the term "good roads" ought to include the proper care of the roadsides, as well as the grading and macadamizing of the roadbeds themselves.

There are at present so-called "weed laws" in many States, and, though more or less of a dead letter in most cases, these laws are steps in the proper direction. The time when insect pests will be looked upon in the eye of the law as so many public nuisances, and

the harboring of them a corresponding crime, may be a long way off, but as it gradually draws nearer we shall come to learn that after all it is the rational view to take and will go far toward solving not only the chinch-bug problem but many others of a similar nature. So far as the chinch bug is concerned, when we burn over the waste lands and accumulated rubbish about our farms in autumn or winter, we are simply applying the same check that the dusky savage did when he lighted the prairie fires, though unwittingly and for an entirely different purpose. In the timothy meadows of the northeastern portion of the country, where, for lack of wings fitting it for locomotion, the chinch bug does not so largely migrate to the waste lands in autumn, the problem is somewhat different, and it will require some careful experiments to determine the exact effects both on the hibernating chinch bugs and on the grass roots of burning over the meadow lands in winter. There can be little doubt, however, that a rapid rotation of crops, so as not to allow the short-winged form to become thoroughly established in a meadow, and the burning over of waste places, thus destroying such rubbish and débris as will serve to offer hibernating places for the long-winged form, will go far toward settling the chinch-bug problem in grass lands.

As previously stated, the chief drawback in putting preventive measures in force is the difficulty of foretelling an invasion. In northeastern Ohio in 1897 hundreds of acres of timothy meadow were destroyed after the hay crop had been removed, but so late that the farmers did not suspect the true condition of their meadows until the spring of 1898, when the young grass failed to put forth and an examination revealed the fact that the roots had been killed, the abundance of chinch bugs pointing unerringly to the cause of the trouble, though in many cases a heavy crop of hay had been removed the previous year where now the ground was entirely bare. While in the case just cited a previous knowledge of the presence of chinch bugs in these meadows might not have enabled the owners to have saved them in the fall of 1897, yet the fall plowing of the land, possibly early enough to have sown the ground to fall wheat, would have buried the majority of the bugs so deeply in the soil as to have killed vast numbers of them and thus prevented their migrating to other lands in the spring of 1898. A rotation of crops that would have included grass for not to exceed two successive years, followed by wheat, would have amounted to precisely the same remedial measure as the one suggested.

A case in northeastern Ohio has come to the writer's notice where an infested timothy meadow was plowed late in the fall of 1897. Late in April of 1898 this ground was cultivated, rolled, and harrowed

several times and most carefully and completely prepared for corn, which was planted, but with the result that a portion of the field was attacked and destroyed by chinch bugs, largely of the short-winged form. An examination about June 10 revealed the bugs in considerable numbers about the plants still remaining, but scattered over the field were more or less numerous clumps of timothy, in some cases apparently killed by the chinch bugs, while in others the bugs were literally swarming about the dying but still green clumps of grass, thus showing that they had either not been buried by the plowing and cultivation of the ground or else the grass had not been thoroughly covered, and thus ladders had been left whereby the bugs were enabled to climb to the surface.

### SUMMARY OF REMEDIAL AND PREVENTIVE MEASURES.

In summing up the matter of remedial and preventive measures for the control of the chinch bug, it may be stated that the insects can be destroyed in their places of hibernation by the use of fire. They can, under favorable meteorological conditions, be destroyed in the fields, if present in sufficient abundance during the breeding season, by the use of the fungus *Sporotrichum globuliferum*, if promptly and carefully applied. They can be destroyed while in the act of migrating from one field to another by tarred barriers or deep furrows supplemented by post holes and by burying them under the surface of the ground with the plow and harrow, or the latter method may be applied after the bugs have been massed upon plats of some kind of vegetation for which the bugs are known to have a special fondness, these decoy plats being so arranged as either to attract the females and induce them to oviposit therein or to intercept an invasion from wheat fields into cornfields. When these decoys have been turned under with a plow and the surface immediately smoothed and packed by harrow and roller the bugs will be destroyed, while in the cornfields they can be destroyed on the plants by the application of kerosene emulsion. Without vigilance and prompt action, however, only indifferent results are to be expected from any of these measures.

### PROSPECTS OF A FUTURE OUTBREAK.

The past history of the chinch bug in America indicates a series of years of the insects' abundance and destructiveness, followed by periods of comparative immunity from its attacks. For a number of years there have been no serious ravages and, in fact, until within the past two years the pest has hardly been noticed by farmers; but within the last year (1908) there have come a number of complaints of serious injury, and, while these outbreaks have so far been of a rather localized character, they seem nevertheless to betoken the

drawing to an end of the period of immunity and the beginning of a series of years of abundance and destruction. These somewhat portentous reports have come from the farmers of Ohio, Indiana, Illinois, Kansas, and Texas. Strangely enough, the city man has not been allowed to rest unmolested and reports of serious ravages by chinch bugs on lawns have come from the widely separated points, Brooklyn, N. Y., and Palm Beach, Fla. It is because of these ominous reports that this publication has been prepared at this time with the hope not only of sounding a note of warning, but also, if possible, of impressing upon the farmer the necessity of watchfulness and the prompt application of preventive measures where the insect is found to occur in any considerable numbers. The Bureau of Entomology has the present summer (1909) been carrying out much experimental and demonstrative work in the West, notably in Kansas.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *September 16, 1909.*

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CIRCULAR No. 114. Issued November 24, 1909.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE EUONYMUS SCALE.

(*Chionaspis euonymi* Comstock.)[a]

By J. G. SANDERS, M. A., *Assistant.*

## INTRODUCTION.

The most serious enemy of the various species and varieties of Euonymus in the eastern United States is commonly known as the Euonymus scale. The injuries occasioned by the attacks of this pest

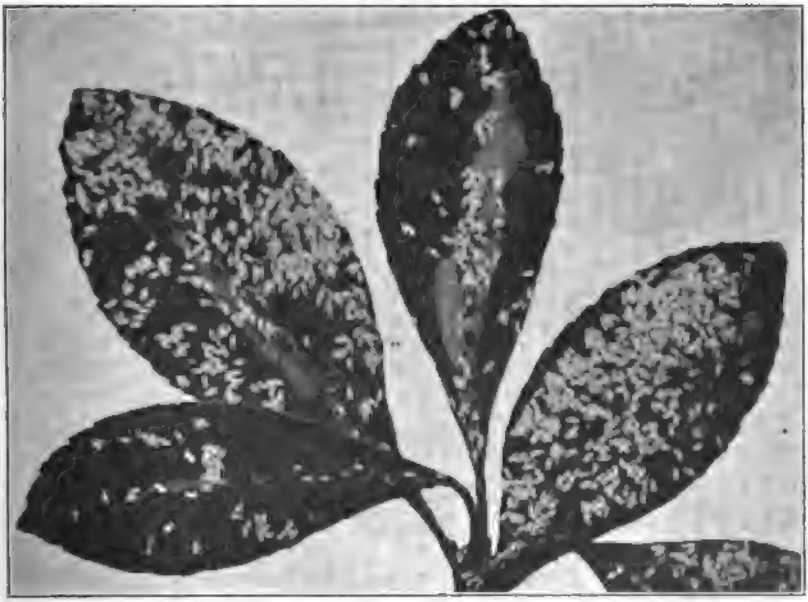

FIG. 1.—A twig of Euonymus moderately infested with Euonymus scale. (Original.)

almost preclude the growing of these beautiful plants for hedges and borders, while the dire experiences of some gardeners have caused them to abandon entirely the use of these plants for decoration.

[a] First described in the Annual Report of the Commissioner of Agriculture for 1880, p. 313 (1881).

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The attacks of this scale insect are almost exclusively confined to Euonymus, although it has been found infesting the common wild bittersweet (*Celastrus scandens*), especially when growing in proximity to infested Euonymus. The native wild species of the latter plant and the introduced and horticultural varieties seem to suffer to the same extent from the attack of their common pest, and it is no uncommon sight to see plants of our wild species dying in the open forests and woodlands.

In 1886 Lichtenstein reported that at Montpellier, France, this scale was so destructive to Euonymus that it rendered the cultivation of that plant almost impossible; and more recently from Japan come reports of serious injury to *Euonymus japonica*.

### HOST PLANTS.

This insect was first brought to the attention of the scientific world in the Agricultural Report for 1880 by Prof. J. H. Comstock, then U. S. Entomologist, who reported that it had destroyed nearly all the plants of *Euonymus latifolia* in Norfolk, Va. There are records of its injury to *Euonymus japonica*, *E. europæus*, *E. radicans*, *E. atropurpureus*, variegated and other horticultural varieties of Euonymus, and *Celastrus scandens* (bittersweet).

### DISTRIBUTION.

Records are at hand of the occurrence of this scale in the following States, and it no doubt occurs in many others: Massachusetts, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, North Carolina, South Carolina, Georgia, Ohio, and California. It is also reported from France, Italy, and Japan.

### DESCRIPTION.

This scale is exceedingly prolific. A plant which becomes infested is soon so completely covered that the attack results in its early destruction. There are at least two broods each season, and a probable third one in the Southern States.

A badly infested plant appears as if covered with snow, this condition being due to the presence of the enormous number of the pure white male scales, which are more conspicuous than the brown female scales. The photograph (fig. 1) of a moderately infested twig of variegated Euonymus conveys an idea of the general appearance of this scale. Note the comparatively few, elongate-oval, brown female scales as contrasted with the great number of the narrow, white, tricarinate scales of the males.

As in all the scale insects of this class, the female Euonymus scale is permanently fixed to one location except for a few hours or days in

the first larval stage, when it appears as a tiny yellow object with six legs which are atrophied before it reaches the adult stage. The male and female larvæ are similar in the first stage, but later the male acquires a pair of delicate wings and emerges from its scale covering a free insect which never feeds, since its mouth-parts are replaced by extra pairs of eyes.

The following short technical description with accompanying illustration (fig. 2) is appended for entomologists or persons who have access to a compound microscope:

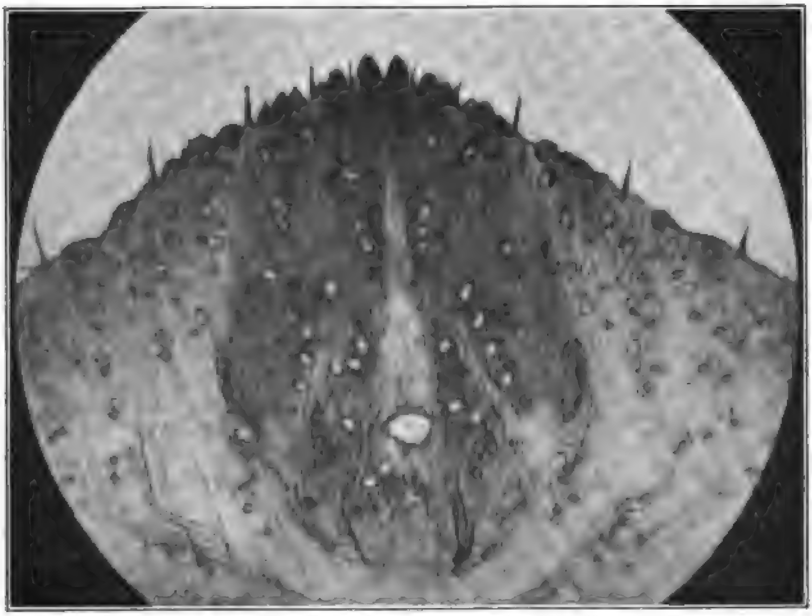

FIG. 2.—Photomicrograph of pygidium of adult female Euonymus scale (*Chionaspis euonymi*). (Original).

*Scale of female.*—Dark brown, with yellow exuviæ, of heavy texture, convex, broader posteriorly. Length, 1.75 to 2 mm. Ventral scale white, completely developed, attached to upper scale along the sides but free posteriorly.

*Scale of male.*—Pure white, parallel sided, strongly tricarinated, with yellow exuvia. Length, 1 to 1.25 mm.

*Female.*—Broadest at fifth segment and tapering anteriorly and posteriorly. Median lobes and lobules of second and third lobes serrulate and pointed, widely separated; lobules of second and third lobes parted to the base, the inner always the larger. Gland spines comparatively short. Five groups of paragenital pores; median, 4–6; anterior lateral, 5–9; posterior lateral, 3–4.

## REMEDIES.

For the control of this pest two distinct treatments are available, viz, summer and winter treatment, each having advantages and disadvantages. Arsenical poisons (Paris green, etc.) are of no avail in

combating scale insects which suck the juices of plants; instead, a corrosive or oily contact insecticide is necessarily used.

### SUMMER TREATMENT.

All scale insects are protected by waxy coverings of different kinds, except in the young larval stage, in which stage they are most easily destroyed by insecticides. The most effective treatment which is least injurious to the plant is the use of kerosene emulsion sprayed with some force on all parts of an infested plant at the time of the hatching of the young, using special care to cover thoroughly both sides of all leaves and twigs. The time of first hatching of the young varies with the seasons and latitudes, and extends from the first of May to the middle of June in different localities. Where no frost occurs the dormant season is very short. Repeated thorough sprayings of infested plants at intervals of two weeks between the above dates should effectively control this scale. Emulsion stronger than 15 per cent of oil should not be used on plants during the summer, else the foliage might suffer.

### WINTER TREATMENT.

During the winter season plants are dormant and are able to withstand stronger insecticides without injury. The deciduous species of Euonymus should be treated after the falling of the leaves, or during winter, with a 25 per cent kerosene emulsion, or a solution of whale-oil soap at the rate of 1 pound to a gallon of water. The evergreen species and varieties can withstand 20 per cent kerosene emulsion during the dormant season. Care should be used to prevent the collection of the oily emulsion at the base of a treated plant, else injury may result.

Directions for the preparation of kerosene emulsion and the proportions of the ingredients are given below:

### KEROSENE EMULSION.

Stock solution (66 per cent oil).

| | | |
|---|---|---|
| Kerosene (coal-oil, lamp-oil) | gallons.. | 2 |
| Whale-oil or laundry soap (or 1 quart soft soap) | pound.. | ½ |
| Water | gallon.. | 1 |

Dissolve the soap in boiling water, *then remove from the fire*, add the kerosene immediately, and thoroughly agitate the mixture until a creamy solution is obtained. This can be done by pouring the mixture into the tank of a spray-pump and pumping the liquid through the nozzle back into the tank. This is a stock solution which must be diluted before using. In order to make a 20 per cent emulsion, add to each gallon of the stock solution about 2⅓ gallons of water and agitate thoroughly before using. For a 25 per cent solution add to each gallon of the stock solution 1⅔ gallons of water and agitate thoroughly. This

strength will kill a large percentage of the hibernating females without injury to the plants.

If a good naphtha soap can be obtained the preparation of the emulsion will be simplified. It will be unnecessary to heat the solution, since the kerosene will combine readily with the naphtha and soap and form a perfect, cold, milky-white emulsion when the mixture is thoroughly agitated. If naphtha soap is used, double the amount called for by the formula, and emulsify in soft (rain) water.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *October 11, 1909.*

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# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE HORN FLY.

(*Hæmatobia serrata* Rob.-Desv.)

By C. L. MARLATT, M. S.,

*Assistant Entomologist and Acting Chief in Absence of Chief.*

### INTRODUCTION AND SPREAD.

The horn fly is one of the worst of the European biting flies that attack cattle, but, curiously enough, it failed to reach this continent until a comparatively late date, notwithstanding abundant importations of live stock from Europe during nearly three centuries. It

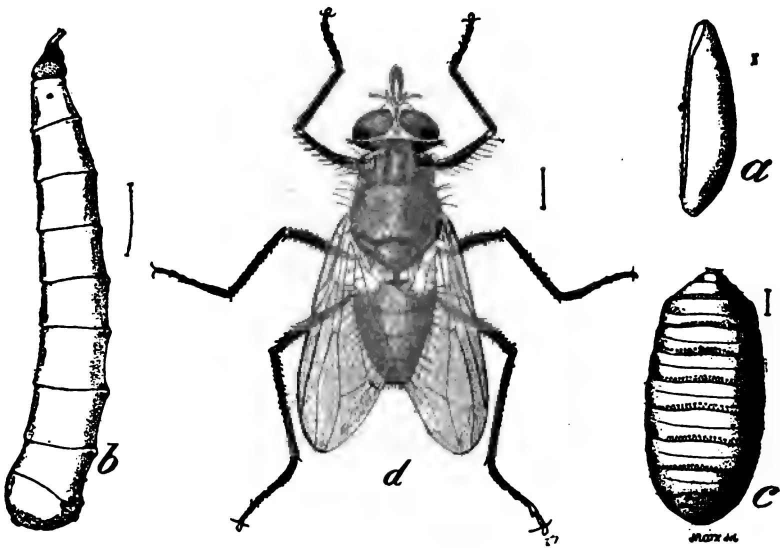


FIG. 1.—Horn fly (*Hæmatobia serrata*): *a*, Egg; *b*, larva; *c*, puparium; *d*, adult in resting position. Much enlarged. (From Riley and Howard.)

was first discovered and reported to this Bureau in the fall of 1887 as occurring near Camden, N. J. The following year it appeared in Maryland and Virginia, and thereafter spread rather rapidly, and by 1891–1892 it was found over the continent from Canada to Texas

and from Massachusetts to the Rocky Mountains. It has not been reported as an especially injurious pest in California, but undoubtedly occurs there, and was carried with cattle from the western coast of the United States to Honolulu in 1897. The following year it had spread to all the islands of the Hawaiian group, and, under a favoring climate which permits multiplication to go on the year round, it had become a perhaps worse pest on these islands in the middle of the Pacific than in the United States.

The first appearance of the fly in New Jersey and Pennsylvania makes it evident that it was brought to this country on European cattle in the early eighties. In the first publications on the subject it was stated that the fly was probably brought in through the port of Philadelphia in 1886, but the records of the Bureau of Animal Industry indicate that the importation of cattle through Philadelphia was discontinued early in 1885. From this fact either the fly was imported a year or more earlier than has hitherto been supposed, or else the fly must have come with cattle through some other port, probably New York. The former supposition, from the early records of distribution of the fly, seems the more likely.

## EARLY INVESTIGATIONS.

The early records of the horn fly in 1887 and 1888 gave little indication of its future importance to stockmen, but in 1889 much excitement was aroused by the pest in New Jersey and throughout Maryland and in Virginia by the rapid spread of the fly and the excessive damage from it to cattle. This Bureau at once began a thorough investigation of the subject, largely conducted by Dr. L. O. Howard, assisted by the writer, and the life history and habits of the insect were worked out with fair thoroughness during this year.[a] In the same year it was being studied in New Jersey by Prof. J. B. Smith,[b] and during the years immediately following it was the subject of investigation and report by most of the official entomologists of this country and Canada. More recently it has been studied in Hawaii by D. L. Van Dine and Jacob Kotinsky, and the rearing of parasites and other natural enemies has been undertaken in Texas by agents of this Bureau for the benefit of and in cooperation with the Hawaiian authorities.

The fly was early determined as the European cattle-biting fly named above, as the result of submitting material to eminent Dipterologists of this country and abroad. The insect was originally described from southern France, and its rapid spread and greater

[a] Insect Life, Vol. II, pp. 93–103; Ann. Rep. Dept. Agr. for 1889, pp. 345–348.

[b] Bul. 62, N. J. Agr. Exp. Sta., 1889.

damage in this country in its southward range would indicate that it is a southern European species. This fact may account for the late date of its introduction to America, the chief importations of cattle coming from central or northern Europe.

### COMMON NAMES.

The name "horn fly" was given it at the very start, from its habit, especially early in the season, of settling in large numbers around the base of the horns, and it is now everywhere known by this name. For the first few years, when the fact of its being a new pest was not fully appreciated, various names were given it, some of which applied to other biting gnats, such as "buffalo fly," "buffalo gnat," and "Texas horn fly." The name "horn fly" is so appropriate that the others were short-lived, but this name carries a slight chance of misunderstanding, inasmuch as the insect does not affect the horn, but simply chooses this point as a resting place when it is inactive—largely because the base and inner curve of the horn is a point which the animal can not reach, either by swinging the head from side to side or with the tail, to dislodge the flies.

### THE DAMAGE OCCASIONED BY THE HORN FLY.

The horn fly is a blood-sucking insect, but the damage occasioned by it is chiefly the result of the irritation to cattle which prevents proper feeding and normal assimilation of food, and hence loss of flesh or lessened milk production. There is also the actual loss of blood, which may be considerable when these flies are abundant. The injury by the fly in New Jersey, Maryland, and Virginia during the first year after its introduction was very considerable, and this is true of its first appearance in the wider and wider areas covered by it. After a year or two, however, the cattle perhaps became more used to it, and the natural enemies of other Diptera, beginning to attack it, reduced its numbers to some extent, so that the loss from it was, as a rule, much lessened. Particularly in the West and Southwest, however, the damage from the horn fly continues to be of very serious moment.

During the first years of the horn fly, when it was a new and little understood menace to cattle, the losses occasioned by it were undoubtedly much exaggerated. Nevertheless the loss, when the fly is abundant, is still very considerable, showing in reduced vitality, lack of growth, or lessened yield of milk, the production of milk often being cut down from one-fourth to one-half. In Canada the late Dr. James Fletcher estimated the loss, in Ontario and Quebec, at one-half of the product of meat and milk.

The horn fly exhibits a certain preference for red or other dark-colored cattle, and that such animals are more thickly infested has been frequently noted. When the insects are abundant, however, this preference is not so strongly marked. Occasionally sores are formed on the animals, which in the South and West may become infested with the screw worm (*Chrysomyia macellaria* Fab.). These wounds or sores are, as a rule, only indirectly the result of horn-fly attacks, but are commonly produced by the rubbing of the cattle in efforts to allay the irritation from the bites.

The loss occasioned by the horn fly to other animals is, as a rule, inconsiderable. Sometimes horses are attacked, and especially cow ponies, and injury to sheep, as pointed out by Norgaard,[a] is complicated with sheep scab.

## LIFE HISTORY AND HABITS.

The appearance and abundance of the flies is governed by temperature and rainfall. In the latitude of Washington they are first noticed in May, and become most abundant in July, gradually dwindling to November or until sharp, frosty nights become frequent. Farther south they appear earlier and remain in evidence later. The study of this insect in Texas by agents of this Bureau, notably Mr. J. D. Mitchell, at Victoria, indicates that the fly reaches its first maximum of abundance in May. During the subsequent dry period the fly decreases in numbers until fall rains begin, when a second maximum is reached in late September, which is checked by the frosts of the latter part of October. Continuing on from then until March the fly is kept down to comparatively small numbers by low temperatures. The reduction of the numbers of the fly in Texas by a dry, hot summer is sometimes as great as 95 per cent from the maximum of May.

The characteristic habit of the fly in clustering about the base of the horn is developed only when the flies are abundant. When they average only 100 or so to an animal, comparatively few will be found on the horns. The horn-clustering habit is more noticeable in the spring and early summer than in autumn. The horns are not the only resting places, and many of the flies cluster upon the back, between the head and the fore shoulders, where they can be reached by neither head nor tail. When the cattle are feeding, the flies are found over the back and flank and on the legs, and during a rainstorm they flock beneath the belly. When the animal is lying down, a favorite place of attack seems to be under the thigh and back belly around the udder. The characteristic appearance of the flies on the horn is indicated in the accompanying illustration (fig. 2).

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[a] Rep. Agr. and Forestry, Hawaii, 1905, pp. 171, 211, 212.

In the feeding position the wings are slightly elevated, and are held out from the body at an angle of 60° from the abdomen; the legs are held out widely, and the beak, inserted beneath the skin of the animal, is directed almost perpendicularly (see fig. 3, *c*). Before inserting its beak the fly works its way through the hair close to the skin, but is able at the least sign of danger to rise instantly in flight, to return as quickly. The characteristic appearance of the fly is shown in the accompanying illustration (fig. 1). It is about half the size of the house fly, which it closely resembles, but is much less robust.

Differing from other biting flies, the horn fly normally stays on the cattle night and day, and when not feeding rests on the cattle as already described.

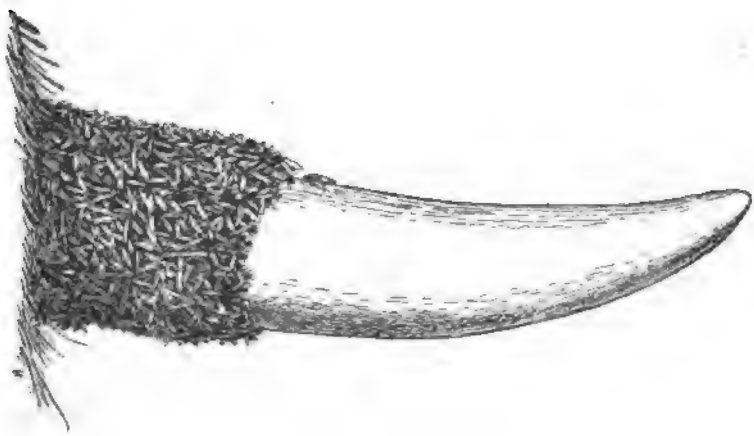

FIG. 2.—Cow-horn showing band of resting horn flies. Reduced. (From Riley and Howard.)

The egg-laying habit of the insect was not easily discovered and is somewhat peculiar. The eggs are laid singly and usually upon their sides upon the surface of wet dung. The moment the latter is dropped, a swarm of flies dart from the animal to the dung and remain there a few seconds, or a minute at the most, during which time many eggs are deposited. Egg laying is chiefly during daylight, between 9 a. m. and 4 p. m., and most abundant during the warmer morning hours. So far as we know, they are laid upon no other substance, and never upon old dung.

The larvæ upon hatching descend into the dung, remaining, however, rather near the surface. When full grown they are about two-fifths of an inch in length and of the normal color and form of the related dung maggots. The puparium is formed in the ground beneath the dung. The time elapsing from the egg to the adult is from ten to seventeen days, and there are probably seven or eight generations annually in the latitude of Washington, with more in the South,

and continuous breeding in a tropical region like the Hawaiian Islands. The winter habits as studied near Washington, D. C., indicate that hibernation normally takes place either in the adult stage or as puparia below the surface of the ground.

## PARASITES AND NATURAL ENEMIES.

The natural enemies of the horn fly, like those of most other dung-breeding flies, are destructive to the insect in its larval and pupal stages. Therefore the bringing over of the insect from Europe in the adult stage with cattle resulted necessarily in its freedom for a time from the control by such natural enemies. The similar enemies of other dung flies in this country, however, undoubtedly very soon began to exercise a certain degree of control, and this may account

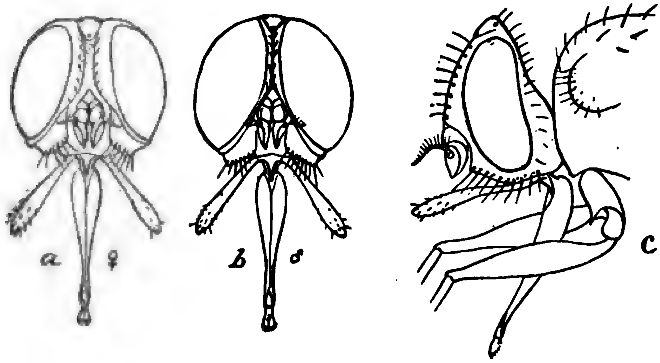


FIG. 3.—Horn fly: *a*, Head of female, front view; *b*, head of male, front view; *c*, head from side. Greatly enlarged. (From Riley and Howard.)

somewhat, at least, for the much greater damage occasioned by the horn fly in the first years of its occurrence in the different zones of its spread across the continent than was the case during subsequent years. Very early after the appearance of the horn fly it was noted by Mr. F. M. Webster that in Ohio fully 20 per cent of the flies were infested by one of the scarlet mite fly parasites (Gamasidæ). This mite was not determined, but was probably one of the native species commonly seen on other flies.

The introduction of the horn fly into the Hawaiian Islands and the heavy losses there occasioned by it led to an active investigation on the part of the island authorities of parasites and predaceous enemies. Mr. Albert Koebele imported, in 1905, from New South Wales, quantities of material from which dung beetles were reared and introduced into the islands. In 1906 Mr. Koebele came to the United States and made extensive collections of material in California and Arizona, and from this material at least six or seven species of dung beetles were introduced into the Hawaiian Islands, and two species of true parasites.

The beetles in question are those which habitually live in cattle dung and feed upon living maggots therein, or are of the tumblebug variety which disintegrate the dung shortly after deposition, thus preventing or checking the breeding of the flies.

The true parasites reared from material sent by Mr. Koebele from Arizona proved to be *Eucolia impatiens* Say, styled "the Arizona dung-fly parasite," and a species of Eutrias, styled "the lesser dung-fly parasite." These two minute four-winged flies are undoubtedly normally enemies of native dung-breeding flies, but take readily to the horn fly. They were reared in considerable numbers and distributed among the ranchmen on the islands. It is too early yet to determine whether these importations will be of much practical value in controlling the horn fly.

Two other similar minute Hymenopterous parasites, belonging to the genus Spalangia, were reared by Mr. Kotinsky from pupæ of the common stable fly (*Stomorys calcitrans* L.), from material collected on the Island of Hawaii. One of these, *Spalangia hirta* Haliday, confined with horn-fly pupæ, promptly attacked the latter, and in three or four weeks a brood of these parasites was successfully reared. Later, horn-fly pupæ collected in the field were found parasitized by this species. The other parasite, *S. lanaiensis* Ashm., supposed to be a native species, was also again reared from Dipterous pupæ. That both of these will become important enemies of the horn fly seems to be established.

## MEANS OF CONTROL.

The simple means of prevention of abundance of the flies by the destruction of larvæ in the dung and the protection of animals from the attacks of the adults, suggested in the earlier investigation of the subject by this Bureau, have remained the standard means of control, with some improvements and amplification enabling them to be carried out on a larger scale and at less cost. There are two principal methods of control—one, the destruction of the larvæ and pupæ in the cattle dung by direct measures or by the action of natural enemies already discussed; and the other, the protection of cattle either by the use of repellent ointments or by the actual capture and destruction of the adult flies.

*Repellents.*—Almost any greasy substance will keep the flies away for from a few hours to several days. A great many oils and fats have been experimented with, and the commercial product known as fish or train oil, first suggested, remains the best easily available ointment. The protection by the use of this mixture varies in different regions. In the dry, hot area of the West and Southwest protection lasts only two or three days; in the more moist and cooler regions of the

East and North, five or six days. This oil costs from 50 to 75 cents a gallon. The addition of a little sulphur or carbolic acid is of benefit, the latter making the application somewhat healing if any sores have been formed. Where only a few animals are to be treated, as a home supply of dairy cattle or a dairy herd, the application can be made with a common painter's brush. It may be unnecessary to attempt to protect the entire animal, but only those parts not reached by the head or tail, although the more completely the animal is covered the greater will be the reduction of loss.

In Virginia Prof. W. B. Alwood found that animals could be treated with the standard insecticide, kerosene emulsion, applied with a small hand-spray pump. This application killed all the flies that were actually wetted by it and gave protection to the treated animals for two days. With a little tobacco water added he found two applications a week sufficient, using from 1 to 2 pints for each animal. The application was made just after milking, and was only tested on dairy animals.

Kerosene emulsion is prepared after the following formula. The crude oil yields a stronger and more lasting product:

| | |
|---|---|
| Petroleum, refined or crude.......gallons.. | 2 |
| Whale-oil soap (or 1 quart soft soap).......pound.. | ½ |
| Water (soft).......gallon.. | 1 |

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the oil. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely and should be diluted only as wanted for use.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water, and more or less of the oil will be freed, especially when the emulsion is diluted. Before use, such water should be broken with lye, or rain water should be employed.

It may be used pure or diluted with one part of water for local applications with a brush, or with two or three parts of water as a spray.

A mixture recommended by the Kansas Experiment Station,[a] claimed to be as satisfactory and considerably cheaper than fish oil, is made after the following formula: Pulverized resin, 2 parts, by

[a] Press Bul. No. 65, March 20, 1900.

measure; soap shavings, 1 part; water, ½ part; fish oil, 1 part; oil of tar, 1 part; kerosene, 1 part; water, 3 parts. Place the resin, soap shavings, ½ part of water and fish oil together in a receptacle and boil till the resin is dissolved. Then add 3 parts of water, following with the oil of tar mixed with the kerosene. Stir the mixture well and allow it to boil for fifteen minutes. When cool the mixture is ready for use, and should be stirred frequently while being applied. This mixture costs about 30 cents a gallon, and from one-eighth to one-half pint is sufficient for one application with the brush method.

The methods just described are not applicable to large grazing herds or cattle on the range.

*Fly control on the range.*—For the control of the horn fly on range cattle on a large scale the dipping-vats system employed for the control of the cattle tick or other skin parasites offers the best solution of the problem. The oily dips used for the Texas-fever tick, described in a publication of the Bureau of Animal Industry of this Department[a] can be made to serve as a very effective means of controlling the horn fly. It was early discovered that dipping cattle in these oily mixtures in the ordinary way was of little service in destroying the horn flies. The cattle dips were repellent to the horn fly for a very short period, and the percentage of the flies killed by the operation was inconsiderable. During the last three years, however, Mr. J. D. Mitchell, an agent of this Bureau, working with Mr. W. D. Hunter in Texas, has, in a study of the requirements for horn-fly control, found that by a very simple modification of the ordinary dipping vat a very large percentage of the flies on the cattle can be destroyed, with the consequent very notable limiting of the loss from this fly pest. With the vats as ordinarily constructed, most of the flies abandon the animal at the moment it plunges into the dip and escape, and go to other animals, and ultimately with the drying of the dipped animal return to it. Mr. Mitchell found, however, that by putting a splashboard near the top of the vat on either side, about 4 feet above the level of the dip, the water thrown up violently as the animal plunges in is caught by these splashboards and is thrown back as a spray, filling the air space above the animal and drenching and destroying the flies in their effort to escape. The few of the horn flies that may escape, together with those which abandoned the animal at the entrance to the vat, were observed to hover or settle on the chute fence, and many would alight on the next animal coming along. He also found that where the animals have been heated in corralling and getting them into the chute the flies stick much closer and are much less apt to take quick flight, thus insuring the capture of a larger percentage of them by the dip and spray.

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[a] Farmers' Bulletin 378, October, 1909.

The first suggestion of splashboards was not as a means of controlling the horn fly but to keep the fluid from wasting over the sides of the vat and to protect the men who were working near the vat. When a large animal strikes the fluid the splash will fly as high as 6 feet, and the spray will scatter widely.

The accompanying detailed sketches illustrate two vats equipped with splashboards which have been used very successfully for a number of years in Texas. The first sketch (fig. 4) is a cross section of the vat constructed by Mr. J. J. Welder, Victoria County, Tex. A ground plan of the entrance is illustrated in figure 5. Mr. Welder's vat is a rather large one, having a surface level of the dip 5 feet wide but with an entrance chute to the vat of only 3 feet and 9 inches. The splashboards are 2 feet wide and 20 feet long, extending from the termination of the entrance chute. In the case of this dipping vat the animal is confined to the middle of the vat and entirely away from the splashboards by the narrow entrance chute.

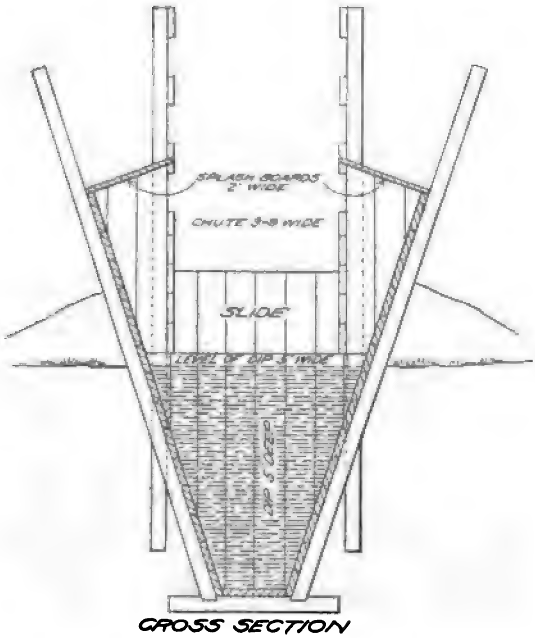


Fig. 4.—Cross section of dipping vat used by Mr. J. J. Welder. (Original).

Another similar vat is illustrated in figure 6. This vat was constructed by Mr. A. P. Borden on the Pierce Ranch, Wharton County, Tex. The splashboards are 1 foot wide and extend the full length of the vat, and can be used, if necessary, as a walk in assisting cattle in trouble. The ends of the splashboards next to the entrance are rounded off in the case of this vat; but the entrance slides, as illustrated in the ground plan of the Welder vat (fig. 5), and the height of the splashboards above the dip level, have in the actual treating of hundreds of cattle prevented any difficulty of catching or colliding of the animals with the splashboards, and were used on a number of vats in Texas most successfully during the years 1907 to 1909.

With vats equipped like the above, from 75 to 80 per cent of the horn flies on the cattle are destroyed.[a]

Mr. Hunter experimented with a small model of a dipping vat, and found that if the splash were received on a slightly curved galvanized-iron sheet instead of a board it was considerably more effective in distributing the back throw of the water in the form of an efficient spray.

The arsenical dips used for the cattle tick would have comparatively little value for the horn fly except that very likely a good many flies might be caught and destroyed by merely being wetted with the dip.

A similar treatment has recently been the subject of experiment in the West. An apparatus has been constructed, designed more particularly for the destruction of skin parasites of cattle, to supplant the old method of dipping in a vat. It has been suggested that this apparatus will furnish a very good means of control in the case of the horn fly. The probabilities are, however, from the experience with the horn-fly traps referred to below, that most of the flies would abandon the cattle at the moment of entrance to the cylinder, and its efficiency as a means of horn-fly control is very problematical.

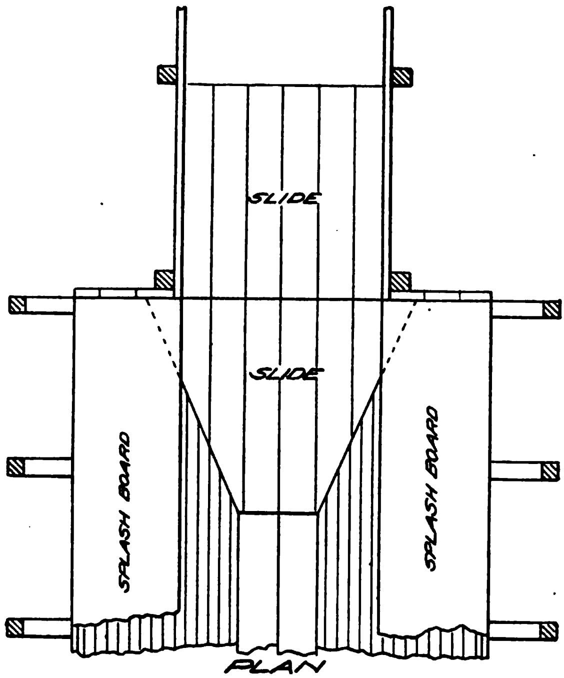

FIG. 5.—Ground plan of dipping vat used by Mr. J. J. Welder. (Original.)

The process consists in driving the animals through a large cylinder through the sides of which a powerful gasoline pump causes sprays of the insecticide to strike the animals from all quarters and thoroughly wet them. This machine is patented and is sold at a rather excessive price. The liquid used is an emulsion of crude petroleum

[a] For further details of the construction of dipping vats see Farmers' Bulletin 378, "Methods of Exterminating the Texas Cattle Tick," by H. W. Graybill, Bureau of Animal Industry. In the case of the vat there described, to successfully use the splashboard it may be necessary to increase the height of the sides of the vat so that the splashboards can be placed 4 feet or a little more above the level of the dip.

in water in the proportion of 20 gallons of oil to 80 gallons of water, with the addition of 5 pounds of soap. This apparatus is claimed to be able to take care of from 3,000 to 4,000 head of cattle per day. With this or some similar device the control of the horn fly ou a broader scale may prove practicable.

*Horn-fly traps.*—Various attempts have been made to collect horn flies from cattle by means of traps, the general plan being to pass the

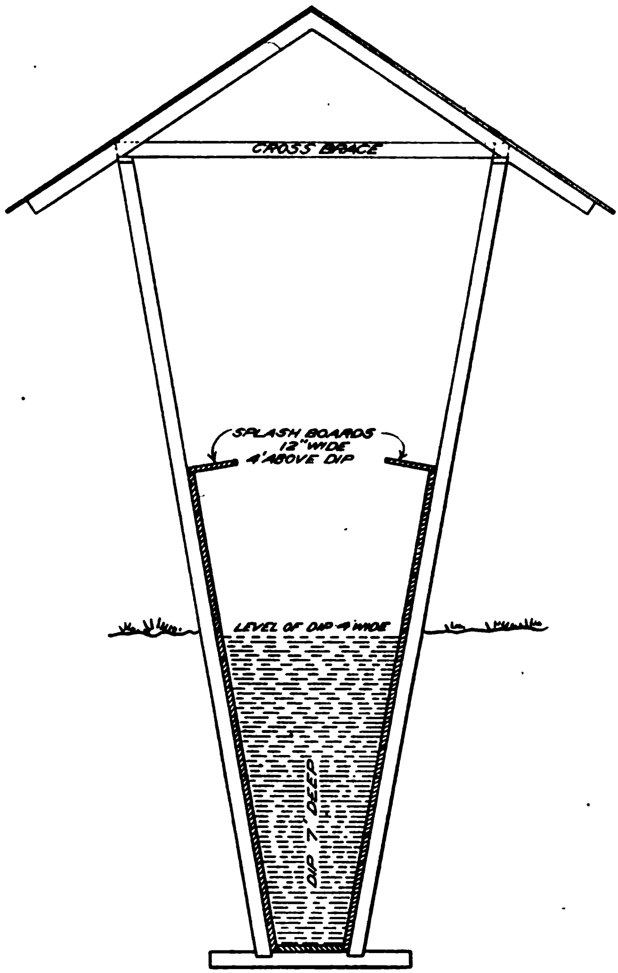


FIG. 6.—Cross section of dipping vat used by Mr. A. P. Borden. (Original.)

cattle through a dark room or chamber arranged with brushes at the exit to drive the flies from the cattle and retain them in the chamber, where they may be attracted to a lighted cupola, captured, and destroyed. Mr. P. J. Parrott, while connected with the Kansas Experiment Station, conducted elaborate experiments in this direc-

tion,[a] but the results were most unsatisfactory, the great majority of the flies abandoning the cattle at the moment of entrance, so that only about 5 per cent of the flies were captured.

*Destruction of larvæ and pupæ.*—The destruction of larvæ and pupæ in the dung by direct measures and consequent reduction in the numbers of the adult insects is a possible means of control, not, however, always practicable, and having little utility in the case of range animals. Two methods of locally destroying the flies in the dung have been shown to be fairly effective. A spadeful of lime thrown on cow dung will destroy the larvæ living in it, and in small pastures such treatment of dung, especially at points where the cattle are more apt to congregate, may be feasible. This treatment is especially useful if carried out during May and June, as every larva killed of the early broods means a very large reduction in the number of flies for midsummer and later in the season.

Prof. J. B. Smith suggests another means of control, namely, the spreading out of the fresh dung with a shovel, which causes the rapid drying of the dung and the destruction of the Dipterous larvæ contained in it. This method also is feasible only in the case of small pastures and in dry weather. An inexpensive method, suggested by Mr. D. L. Van Dine, of scattering the dung in yards and pens and causing it to dry quickly is to allow a number of pigs to run with the cattle. In their efforts to obtain undigested particles of food the pigs will effectually destroy the dung as breeding places for the fly, at least during dry periods.

A dairyman in Texas, as reported by Mr. Hunter, has followed an analogous method of control which has given him very considerable protection from the horn fly. He makes it a practice to collect daily the dung in and near the dairy barns, and every few days this collected material is taken out and distributed with a spreading machine on the pasture, so that it promptly dries up and the breeding of larvæ in it is prevented. Wherever this practice is feasible it is to be strongly recommended, and has the important additional argument in its favor of conserving the valuable manurial material which might otherwise go to waste.

In the same way, as observed by Mr. Mitchell, during the dry period of July and August in western Texas the horn fly is very much reduced in numbers by the rapid desiccation of the cow droppings.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *November 17, 1909.*

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[a] Kansas State Agr. Coll. Exp. Sta., Press Bul. No. 49, November 7, 1899.



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CIRCULAR No. 116. Issued February 7, 1910.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE LARGER CORN STALK-BORER.[a]

(*Diatræa saccharalis* Fab.)

By George G. Ainslie,

*Associate Professor of Entomology, Clemson Agricultural College of South Carolina.*

## INTRODUCTION.

In many southern cornfields a heavy wind late in the season, before the corn is matured, does great damage by breaking the plants off at the surface of the ground, thus ruining them. An examination of these broken stems will, in most cases, show that they have been greatly weakened by the burrows of a larva or caterpillar. This larva (fig. 1) is known as "the larger corn stalk-borer" (*Diatræa saccharalis*). Its work is largely within the stem of the plant and is so concealed that, in most cases, unless weather conditions make it conspicuous, the presence of the insect passes unnoticed.

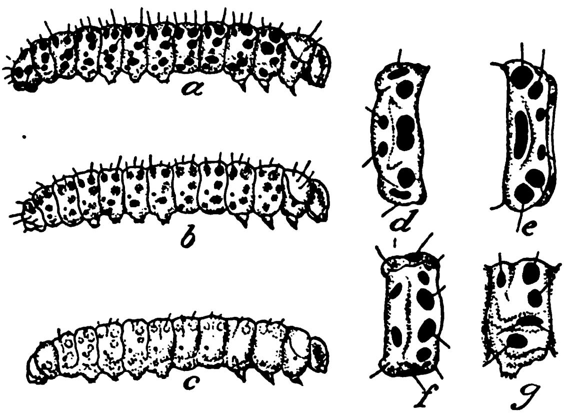


Fig. 1.—The larger corn stalk-borer (*Diatræa saccharalis*): *a*, Summer form of larva; *b*, *c*, hibernating forms of larvæ; *d*, third thoracic segment from above; *e*, eighth abdominal segment from above; *f*, abdominal segment from above; *g*, same from side. *a*, *b*, *c*, Enlarged; *d*, *e*, *f*, still more enlarged. (Redrawn from Howard.)

[a] This is practically a revision of Circular No. 16, prepared many years ago by Dr. L. O. Howard. Mr. Ainslie was formerly in the employ of this Bureau as an agent and expert in cereal and forage insect investigations, and this pest was one of the subjects of investigation assigned to him. He afterwards did some work upon the species for the South Carolina Agricultural Experiment Station in cooperation with this Bureau.

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This insect seems to have been originally an enemy of sugar cane and to have first transferred its attention to corn in the southern part of this country, where corn and cane are grown over the same territory. It occurs in many countries where sugar cane is the staple crop, and has caused great damage in the West Indies, British Guiana, Australia, and Java. The bulk of the evidence goes to show that it was first brought into this country with the importation of sugar-cane cuttings from the West Indies and Central and South America, where, since early times, it has interfered with the production of this staple.

In the United States this borer is found almost universally throughout the South, from Maryland to Louisiana and westward to Kansas. Among other localities it has been reported to the Bureau of Entomology from Bennettsville, S. C., as destroying corn, especially that planted early in the season. From Waynesboro, Ga., in 1909, reports were received that in some fields the corn was "at least one-third destroyed" by an insect which later proved to be this species. In Virginia it has been found recently at Nathalie, where it was studied by Mr. J. A. Hyslop, of this Bureau, at Allenslevel, at Church Road, and at Farmville. In late October, 1909, Mr. E. G. Smyth found that nearly one-half of the cornstalks at Diamond Springs, Va., were infested, often as many as three larvæ being found in one stalk, boring from the surface of the ground down to the base of the root; and while the author has frequently found as many as a dozen larvæ in a single stalk, there are never more than two or three pupæ in the same stalk. In each case it had damaged the corn, and especially that planted early in the season. Detailed investigations of this insect have been conducted by the author during the last two years, chiefly in South Carolina.

## NATURE OF DAMAGE.

Corn is damaged by these caterpillars in two ways. First, in the early part of the season, while the plants are small, they work in the "throat" of the young corn, and if the tender growing tip within the protecting leaves is once damaged all chances that the plant will become a normal productive specimen are gone. In many sections of the South this is commonly known as "bud-worm" injury, and though there are several other insects which cause a similar mutilation of the leaf, a very large proportion of the so-called "bud-worm" damage may be charged to this insect. The effect of its work on the leaves of the young corn plants is similar to that resulting from attacks by the corn billbugs (*Sphenophorus* spp.) and is evidenced by the familiar rows of small circular or irregular holes across the blades of the plant (fig. 2)..

The other form of serious damage chargeable to this pest occurs later in the season. The larvæ, having then left the leaves and

descended to the lower part of the stalk, tunnel in the pith. (See fig. 3.) If the larvæ are at all numerous in the stalk, their burrows so weaken the plant that any unusual strain will lay it low and destroy all chance of its maturing. While frequently ten or more larvæ may live and mature in one plant, it must be remembered that

FIG. 2.—Work of larger corn stalk-borer, showing mutilation of leaves of corn by larvæ. Greatly reduced. (Original.)

any infestation, however light, will lessen in some degree the vitality of the plant and cause a corresponding loss in the quality and quantity of the harvest.

## HABITS OF THE LARVÆ.

Immediately upon leaving the egg in spring, the young larva of the first generation, spinning a silken thread behind it, wanders down into the throat of the plant as far as the water or dew usually standing there will allow it to go, and begins to feed on the leaves, going back and forth through the yet unfolded clusters and soon riddling the more tender leaves with aimless burrows. If the burrow reaches the tender terminal bud where the future joints are being formed, further growth at that point ceases and the plant becomes stunted and misshapen, with no tassel. As the plant continues to mature, the larva "grows out," as the farmers say. It is more

likely that it is the evidences of its work and not the larva itself that "grow out;" but for whatever reason, the caterpillar soon leaves the more leafy portion of the plant and attacks the stalk at or near the ground. Here a hole is cut through the outer wall of the stalk and the larva burrows upward for a short distance, after which it seems to run aimlessly through the pith, frequently even leaving the

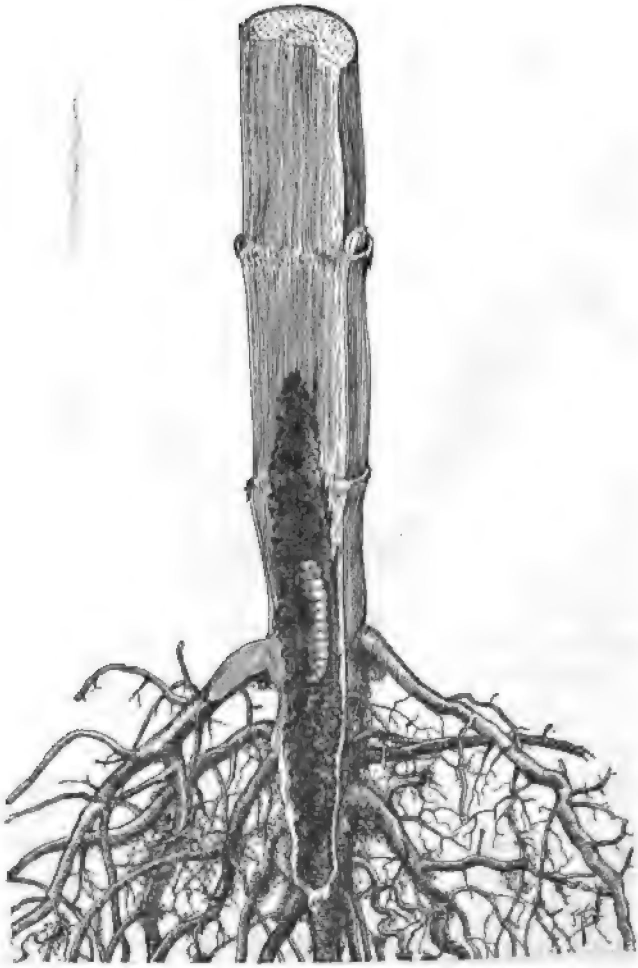

FIG. 3.—The larger corn stalk-borer: Larva in lower part of corn plant preparatory to hibernation. Reduced. (Original.)

stalk entirely and reentering it at another point. Turning upward, the caterpillar, when fully grown, bores toward the outside and cuts a circular hole in the outer wall of the stalk. Then, after spinning a few loose threads across this opening to keep out undesirable visitors, it retreats a short distance, plugs the burrow below with digested pith, and in the chamber thus created slowly changes to the next or pupal stage (fig. 4, *c*).

Seldom is the stalk damaged above the third joint from the ground, although the larvæ, when small, are found in the large midribs of the lower leaves and later in the season, when the food supply is restricted, even in succulent nubbins farther up. They sometimes also penetrate the underground part of the stalk in feeding and enter some of the larger brace roots for a short distance.

The larvæ of the second generation work in a similar manner, except that at the time they appear the tassel has been formed; hence the damage is now confined altogether to the lower stalk. Thus, instead of arranging to pass the pupal stage in the upper stalk, they penetrate to the root to hibernate and there, as larvæ, pass the winter in a quiescent state (fig. 3).

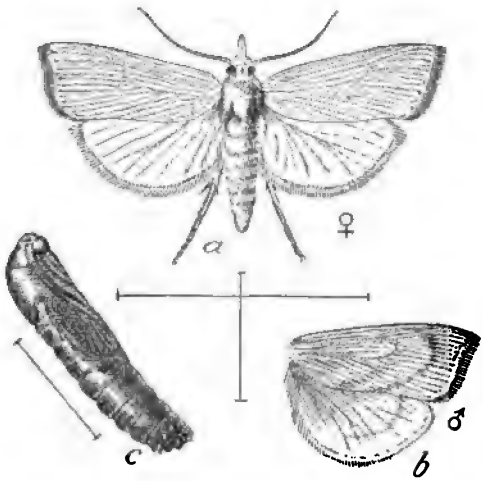

FIG. 4.—The larger corn stalk-borer: *a*, Female moth; *b*, wings of male; *c*, pupa. All somewhat enlarged. (Original.)

SEASONAL HISTORY.

During the winter this enemy of corn is to be found as a robust, creamy-white larva of the second generation in the lower part of the stalk—or of the stubble, if, as is usually the case, the corn has been cut. In this location the larva forms a small cavity below the surface of the ground, well protected from birds, predaceous insects, and unfavorable weather conditions. From the time the corn is mature in the fall until about corn-planting time in the spring this caterpillar remains inactive. About the time the ground is being prepared for corn, from March 15 to April 30, depending on the locality, this larva changes into a reddish-brown pupa or chrysalis (fig. 4, *c*). After a further period of ten or more days' inactivity the adult insect emerges from the pupa case as a pale brownish-yellow moth (fig. 4, *a*, *b*), with a spread of wings of about an inch and a quarter. The moths then mate and the females begin at once to deposit eggs on the underside of the leaves, the larvæ hatching from these eggs forming the first generation.

The eggs hatch in from seven to ten days and the young larvæ begin their destructive work in the upper leafy portion of the plant, later descending to the base of the stalk, where they attain full growth. This period, from egg to full-grown larva, requires from twenty to thirty days, depending largely on the weather conditions

and the vigor of the plant. The larvæ when full grown pupate in the stalk, usually in the second or third joint from the ground, and in from seven to ten days the adult moths of the first generation emerge.

The eggs for the second generation are laid in similar positions on the lower leaves or on the stem, and the larvæ, after feeding for a short time on the leaves, go directly to work in the stalk, completing their larval growth in the pith of the lower stalk as did the larvæ of the first generation. No damage is done to the upper part of the plant by larvæ of the second generation.

By the time the larvæ of the second generation are full grown the corn is rapidly nearing maturity, and, instead of pupating in the stalk, they turn downward, penetrate to the extreme lower tip of the taproot, and there form a small cavity in which to pass the winter. At this time the larvæ lose the darker markings of the earlier forms, and as overwintering larvæ are creamy-yellow in color. They are plump and active in the fall, but flabby and sluggish after fasting throughout the winter. The only way in which the insect passes the winter is in the form of this overwintering larva, found below the ground in the extreme lower tip of the corn roots. Two generations a year appear to be the rule, although it is possible that in the far South and on sugar cane a partial third generation may occur.

## DESCRIPTIONS.

*Egg.*—The eggs are flat and scalelike, almost circular in outline, and are placed in rows or irregularly, overlapping one another shingle fashion. From two to twenty-five eggs are laid in one place on the underside of a lower leaf or occasionally on the upper side and on the stem. Creamy-white when first laid, they gradually change to a reddish-brown, and in seven to ten days a minute, bristly, reddish caterpillar cracks the shell and crawls out through a narrow slit at one end. The eggs are about three one-hundredths of an inch (7.6 mm.) long and about two-thirds as wide. After hatching, the white papery shells are soon washed off the leaves.

*Larva.*—The larva of the first generation (fig. 1, *a*) when full grown is a robust, dirty-white caterpillar 1 inch in length, thickly covered with round or irregular dark spots, each of which bears a short, dark bristle. When the larva is small these markings are almost contiguous, giving the whole insect a dark color and a hairy appearance. The head and thoracic plate of all the stages are brownish-yellow. The overwintering larva of the second generation (fig. 1, *b*, *c*) gradually loses the darker markings of the body and after the last molt remains unspotted and light yellow in color, except for the head and the thoracic plate, which retain the brownish-yellow of the earlier stages.

*Pupa.*—When first formed, the pupa (fig. 4, *c*) is light honey-yellow in color, soon changing to a rich mahogany-brown. It is about seven-eighths of an inch in length and is able to contort itself violently when disturbed. It lies in the cavity usually with the head up. On emerging, the moth leaves the brownish shell of the pupa case, partially withdrawn from the hole.

*Adult.*—The female moth (fig. 4, *a*) varies in color from almost white to smoky yellow. The fore wings, which spread to about 1¼ inches, are darker than the hind wings, and bear faint markings. When at rest the wings are held close to the body, forming an acute triangle. The egg laying is done for the most part either at night or in the dusk of evening, the moths flying rapidly from plant to plant. The male moth (fig. 4, *b*) is usually somewhat darker in color than the female and always smaller.

## FOOD PLANTS.

Besides corn and sugar cane, this borer has been reported as feeding on sorghum, Johnson grass, guinea corn, and grama grass. The injury to the four last-mentioned plants is never severe, but in planning methods of control they must be considered and an examination made to determine whether or not they are harboring the pest.

## NATURAL CHECKS.

The larger corn stalk-borer has very few natural enemies. A minute Hymenopterous parasite (*Trichogramma pretiosa* Riley) has in a very few instances been found living in and destroying the eggs. In one case ten of these minute parasites were reared from two eggs. The larva of a brown, velvety beetle (*Chaüliognathus pennsylvanicus* DeG.) sometimes enters the holes in the stalks of stubble after the corn is cut and devours the caterpillars found therein. This larva has been found to be of great value in reducing the numbers of the borers in fields of sugar cane. The termites or white ants (*Termes flavipes* Koll.), locally known as "wood lice," have been observed destroying the larvæ in the stubble in the winter, although apparently only when the presence of the larvæ interfered with the work of the ants. In a few cases bodies of the borers have been found in the stubble killed by a fungus, as yet undetermined, which envelops their bodies in a white mold. Fungi, however, are too dependent on weather conditions to be of any practical value in controlling the pest.

## PREVENTIVE MEASURES.

Rotation is one of the best general preventives of injury from insects affecting field crops. Experience has shown that where corn has followed itself upon the same field for two or more years there has been a much greater loss from the borer than where an annual change of crop has been practiced. This is especially noticeable

where stalks or stubble from the previous year have been allowed to remain undisturbed throughout the winter. The moths, upon emergence in the spring, finding themselves surrounded by the young corn, commence egg laying at once and escape the dangers encountered in searching for another field of corn. A forced journey in search of young corn results in many of the females being eaten by birds or being destroyed because of rain, cold, or failure to find the object of their quest. A few moths will always succeed in their search, but the successful proportion will be greatly decreased by persistent crop rotation.

Another remedy, probably the best for this insect, is the thorough destruction, some time before the period of emergence of the moths in the spring, of all the stalks and stubble remaining in the field from the preceding crop. If all this trash can be disposed of before the opening of spring, the numbers of the pest must be greatly diminished if not almost exterminated, for the only form in which the insect passes the winter is that of the caterpillar, and the only known location is in the lower tip of the corn root, snugly hidden. Some few may, however, be found to survive in the roots of the larger grasses mentioned above, and care should be taken in such cases to treat these in the same way. The method employed in disposing of the stubble and stalks will depend largely on the conditions in individual cases. If the stubble is cut low and the land is moderately heavy, a thorough deep plowing may suffice, an inch or two of well-settled soil being sufficient to prevent the escape of the adult moths. Bringing the stubble to the surface where it can dry will kill some of the contained larvæ, but this method depends too much on the state of the weather to be trusted. By far the most effective plan is to remove the stubble from the field with a rake and burn it.

In the cane field the methods of treatment must be adjusted to correspond with the methods of handling that crop. The larvæ commonly spend the winter in the trimmings and tops which have been discarded at harvest time because of immaturity. This refuse, left on the ground throughout the winter, becomes dry and inflammable and, if thoroughly burned before spring, enough larvæ will be killed to insure at least temporary relief from the ravages of the borer.

Any method which will insure the complete destruction of the overwintering larvæ, if persisted in and carried out simultaneously over large sections of the country, will effectually preclude serious damage from the insect.

Approved:

James Wilson,
*Secretary of Agriculture.*

Washington, D. C., *December 14, 1909.*

CIRCULAR No. 117. Issued February 25, 1910.

# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE WESTERN GRASS-STEM SAWFLY.

(*Cephus occidentalis* Riley and Marlatt.)

By F. M. WEBSTER,
*In Charge of Cereal and Forage Insect Investigations,*
and
GEO. I. REEVES,
*Special Field Agent.*

### INTRODUCTION.

The western grass-stem sawfly (*Cephus occidentalis* Riley and Marlatt), which has caused much alarm and not a little loss to the wheat growers of North Dakota during the season of 1909, is not by any means a new insect, although this is its first appearance in the

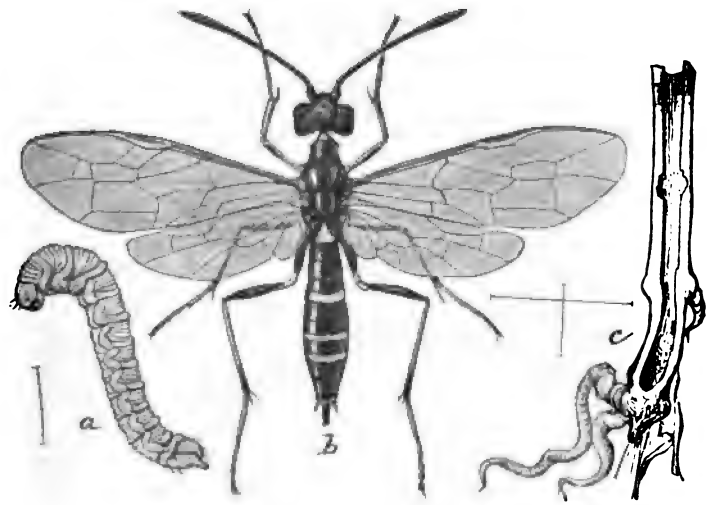


FIG. 1.—Western grass-stem sawfly (*Cephus occidentalis*): *a*, Larva; *b*, female sawfly; *c*, grass stem showing work. *c*, Enlarged; *a*, *b*, more enlarged. (From Marlatt.)

United States as a serious pest. It was first observed in 1890 and has since been reported at intervals as feeding upon grasses and occasionally upon wheat in Canada and the United States. For the purpose of affording farmers all available information relative to the

pest this circular has been prepared. The account of the habits and seasonal history of the insect, list of food plants, and description of both larva and adult represent the work of the many observers mentioned in the paragraph on history and distribution, as do also the closing statements as to natural checks upon its increase, and preventive treatment.

## HISTORY AND DISTRIBUTION.

The first observation on this insect was made by Mr. Albert Koebele,[a] an agent of this office, who found the larvæ burrowing in grass stems in California in 1890, and who reared the adults. From these and others which had been collected in Montana and Nevada the species was described by Riley and Marlatt, who said: "The economic importance of this species arises from the fact that it may be expected at any time to abandon its natural food plant in favor of the small grains, on which it can doubtless successfully develop. Such changes in the food habits of our native insects are constantly occurring to the great detriment of our agriculture, as is illustrated by the attack of the *Nematus* and *Dolerus* species on wheat, these insects normally affecting wild grasses."

The fulfillment of this prophetic suggestion was not long delayed. In 1896 the late Dr. James Fletcher,[b] entomologist to the Dominion of Canada, reported that he had found the adults, which he believed were those of *Cephus pygmæus* L., the European species, at Indian Head, Northwest Territories [Saskatchewan], and that Mr. John Wenman, of Souris, Manitoba, had sent in wheat straws containing larvæ. Mr. Wenman wrote that the damage resulting from this attack was not appreciable. In 1902 Doctor Fletcher[c] found the larvæ numerous in grasses in the Northwest. In 1905, 1906, and 1907 the junior author observed the work of the larvæ in grasses throughout the northwestern United States, and in 1906 found them damaging wheat at Kulm, N. Dak. In his report for the year 1908 Doctor Fletcher again referred to this insect, stating that in the previous autumn it had appeared in central Manitoba and the southeastern part of Saskatchewan in much more serious numbers than at any previous time. "The broken straws which resulted from its attacks were seen in many fields and occasioned some alarm." Mr. Norman Criddle[d]—a farmer and careful observer of insects, of Aweme, Manitoba, and the inventor of the grasshopper poison which bears his name—recognized the insect as *Cephus occidentalis*, and wrote Doctor Fletcher at the end of the season that the species had increased

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[a] Insect Life, Vol. III, p. 71, 1890.

[b] Ann. Rep. Exp. Farms Canada f. 1896, pp. 229–230, 1897.

[c] Letter.

[d] Ann. Rep. Exp. Farms Canada f. 1907–8, pp. 191–192, 1909.

considerably during the last year or two and had turned its attention to wheat and rye. In 1908 the authors found it in grasses in the Willamette Valley in Oregon. In 1909 Prof. H. B. Penhallow, of New York City, writing from Sherwood, N. Dak., stated that it was damaging from 5 to 25 per cent of the wheat in many fields in the Souris Valley, and Mr. R. W. Sharpe, of Fargo, N. Dak., reported similar depredations in the Red River Valley. Larvæ or adults have been found in Manitoba, the Dakotas, Nebraska, Kansas (probably), Saskatchewan, Montana, Wyoming, Colorado, Oregon, Nevada, and California.

## HABITS AND SEASONAL HISTORY.

In Manitoba, according to Mr. Criddle,[a] the eggs are laid singly by the female sawfly (fig. 1, *b*) upon a stem of grass or wheat, not far from the head, between June 20 and the second week of July. "The larvæ (fig. 1, *a*) soon hatch and begin to eat down inside the stem, usually reaching the ground toward the end of August, at which time they mature." They then cut a horizontal ring on the interior of the stem near the surface of the ground so as nearly to sever it, after which they close the cavity below smoothly with a plug of castings and spin a thin, silken, cylindrical cocoon below the plug (fig. 1, *c*). The stem usually breaks off neatly at the engraved ring during the autumn, but may remain in position until winter and possibly longer. "In these retreats," to quote again from Mr. Criddle, "the larvæ pass the winter and remain in an active condition unchanged until May of the following year, when they turn to pupæ, and emerge as perfect sawflies toward the end of June, the date varying somewhat with the season." The adults were taken by Doctor Fletcher,[b] July 5, on the flowers of tumbling mustard.

The injured stem appears discolored between the first and third joints and the larva may be seen through the translucent wall of the stem where it is eaten thinnest. In the case of wheat, the stalk often bends at this point, an inch or two below a joint rather than above as in Hessian fly injury, and the head falls to the ground shortly before harvest. Dr. J. H. Comstock[c] found that the European corn sawfly, an allied species, did not affect the size of the head or of the kernels, but it is well known that grasses have the heads blighted by our species, and Professor Penhallow writes that the heads of wheat are shrunken owing to the diversion of sap at this critical time. If this be generally true, the damage to the crop is much greater than has been estimated from the number of fallen heads. Mr. Criddle[a]

[a] Ann. Rep. Exp. Farms Canada f. 1907–8, pp. 191–192, 1909.

[b] Ann. Rep. Exp. Farms Canada f. 1896, pp. 229–230, 1897.

[c] Bul. 11, Cornell Univ. Agr. Exp. Sta., November, 1889.

states that in a field of wheat at Aweme, Manitoba, 75 per cent of the infested stems collapsed before harvest, but we observed a field at Kulm, N. Dak., to have only 6 per cent of the injured straws broken. The native grasses do not collapse when attacked by this insect and it is possible that some stiff-stemmed wheats may stand up better than other varieties. This is an advantage to the farmer in preventing total loss of the affected heads, but a disadvantage if it prevents him from detecting the cause and extent of a serious shrinkage of the kernels.

The damage has been confined heretofore to the edges of fields bordered by grass lands or roadsides. Mr. Criddle[a] states that 50 per cent of the stand is infested for a distance of 100 feet into the fields, and that the damage is apparent to a lesser extent throughout the crop. He also states that the insect seeks wheat only when it fails to find enough flowering stems of grasses in which to deposit its eggs. Recent reports from North Dakota indicate that the injury may be more general than heretofore and suggest that the insect has probably adapted its habits to conform to the farm methods of that region so that it no longer depends upon native grasses but breeds throughout the fields, at once distributing the damage more evenly and increasing its capacity for harm. A pest which can take advantage of wild food plants and yet be independent of them is far more dangerous than one which can feed only upon wheat or one which requires both wheat and a native grass.

### FOOD PLANTS.

This sawfly is a native insect which has learned to attack wheat and, according to Mr. Criddle, rye also, since these have taken the place of its native food plants—quack grass and wheat grass (Agropyron), brome grass (Bromus), rye grass (Elymus), and timothy (Phleum). It was especially abundant in Agropyron along railroad embankments in North Dakota in 1905 and 1906, so that in many clumps of this grass one-half of the heads were prematurely whitened.

### DESCRIPTION.

The larva (fig. 1, *a*) is about three-fifths of an inch long and one-eighth as wide, slightly larger near the head, and tapering toward the tail, which ends in a small, blunt, upturned, brown tubercle. The body is yellowish white; the head, a spot on the back of the neck, rings on the palpi, the tips of the paired cerci, and the setæ on the last segment, are pale yellow; the margin of the cheeks and of the antennal segments, a faint streak on each cheek through the eye, the mandibles, the stigmata, and the median anal tubercle, are mahogany

[a] Loc. cit.

brown; the mandibles shade to black at the tips and at the hinges; the eyes are black.

The adult (fig. 1, *b*) is a black, shining, four-winged sawfly, about one-third of an inch long, spotted and banded with yellow. The original description[a] is as follows:

The adult insect agrees almost exactly with *Cephus pygmæus* in coloration, coming much closer to it in this respect than to any other American species, but is in every way more slender and graceful and would never be mistaken for the European species. The head is narrower in proportion to the body and is more globular when viewed from the side. Viewed from above it narrows more posteriorly from the eyes than *pygmæus*. * * *

The species may be characterized as follows:

♀ Black; basal joints of the maxillary palpi, large spot on mandibles, two spots beneath anterior wings, membranous regions of thorax, small spot on lower posterior edge of dorsum of first segment, larger one on second segment, band, dentate on basal margin, on apical half of dorsum of third, fifth, and sixth segments, and more or less of the lower and apical margin of the remaining segments, lemon yellow.

Legs black, slender; spot on posterior coxæ above, upper side and tip of femora, yellow; tibiæ and tarsi reddish yellow except tips of posterior tibiæ and their tarsi, which are brownish; last joint and claws of middle and anterior tarsi also brownish.

Antennæ 20–21 jointed, longer than head and thorax, slender to joint 7, beyond which the articles are shorter and thickened.

Wings slightly smoky;. veins brown except costal and margin of stigma, which are yellowish; a small infuscated spot at base of discoidal vein; second recurrent vein joins the third submarginal cell near the base of the cell; cross veins of lanceolate cell slightly curved and oblique.

Abdomen not much longer than head and thorax, strongly compressed laterally.

Length, 9–11 mm.

Exp. al., 16–19 mm.

♂ smaller and more slender than the ♀; abdomen less compressed; antennæ 18–21 jointed. Coloration as in ♀ except a large spot on the clypeus, one just below the eyes in front, the entire pectal region of the thorax, and the posterior margin of the third, fifth, and remaining ventral segments, which are lemon yellow.

The under side of the coxæ, trochanters, and femora, including the apex of the latter above, are lemon yellow; the tibiæ and tarsi are as in the case of the ♀.

In some specimens the femora are entirely yellow or with a narrow black line on the anterior pair above, and the yellow band on the third ventral segment is occasionally obsolete.

Length, 8–9 mm.

Exp. al., 15–17 mm.

Habitat: Santa Clara County and Santa Cruz Mountains, California, Nevada, and Montana.

Described from 24 females and 14 males, of which 25 specimens from California were bred by Mr. Koebele, and 13 from Nevada and Montana were collected.

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[a] Insect Life, Vol. IV, pp. 177–178, 1891.

### NATURAL CHECKS.

Mr. Criddle found that many of the broken stems of infested wheat had bent in such a way as to crush and kill the larva which was working at the point where the stem collapsed. Since the stems of grasses do not break under the attack, this is a danger which the insect has incurred by changing to a new food plant. This form of accident materially reduces the number of individuals which may reach maturity and deposit eggs in the wheat, since from 6 to 75 per cent of the infested stems break near the point where the larva is working, shortly before the larva retreats toward the roots to prepare for hibernation.

Parasites were reared by the junior author from larvæ collected at Minot, N. Dak., belonging to an undescribed species of the Chalcidid tribe Entedonini.

### PREVENTIVE MEASURES.

Mr. Criddle tried burning the stubble in the autumn with the aid of straw scattered over it, but found that the larvæ were not much damaged thereby. A remedy which suggests itself and has been practiced to some extent is the plowing down of all stubble, either in autumn or before June 15, at which time the adults may be expected to emerge and deposit eggs. Grass growing near the edges of fields should be mowed early in July, while the larvæ are small, to prevent them from maturing and attacking the crop of the following year.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *December 24, 1909.*

Issued April 23, 1910.

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 118.
L. O. HOWARD, Entomologist and Chief of Bureau.

# A PREDACEOUS MITE PROVES NOXIOUS TO MAN.

(*Pediculoides ventricosus* Newport.)

BY

F. M. WEBSTER,

*In Charge of Cereal and Forage Insect Investigations.*

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1910

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# A PREDACEOUS MITE PROVES NOXIOUS TO MAN.

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## INTRODUCTION.

While the scientific and medical literature of European countries, and to some extent of Asiatic countries, contains numerous records of mites attacking man, it is difficult to determine, from a perusal of this literature, whether or not the mite *Pediculoides ventricosus* Newport, shown in its most active form by figure 1, has been concerned in these attacks. There is no particular reason why it should not have become noxious to man precisely as, and elsewhere than, in America, because it has doubtless, with its host insect, the Angoumois grain moth, *Sitotroga cerealella* Oliv. (fig. 3), been distributed in grains throughout the warm regions of the globe, wherever these grains have entered into international commerce. While there is a decided similarity between these attacks on man in Europe and America, the writer is unable to select, from the various instances recorded, a single one in which he can unhesitatingly say that this and not some other species of mite was responsible for such attacks. In many cases it is very clearly to be seen that other and very different species of mites have been involved in attacks of a similar nature, both in this country and in Europe. Here in America such troubles

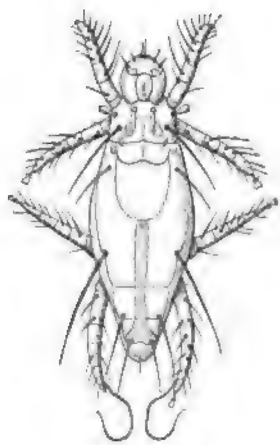

FIG. 1.—Adult female of *Pediculoides ventricosus*, before the abdomen has become inflated with eggs and young. In this condition the mite is nomadic and predatory. Greatly enlarged. (Redrawn from Brucker.)

have until recently been commonly attributed to "chiggers,"[a] which inhabit neither the dried straw nor thrashed grain. The term "chigger" really includes a number of different kinds of mites, notably the young of Trombidium and other insects which inhabit grassy and weedy places and woodlands. This is why it is that people visiting such places are not infrequently attacked and suffer painfully therefrom. While our knowledge of the matter remained in this condition, the possibility of confusing the disease discussed herein with others of a much more serious nature was very great, but now that we understand the causes and know that these causes can be removed, and the physician enabled to distinguish it from an attack of "chiggers" and prescribe proper treatment, much of this danger and painful annoyance may be eliminated. There is also another point that must not be overlooked, namely, that this mite during its period of greatest activity is almost invisible to the unaided eye (see fig. 1). Not every practicing physician possesses a microscope that will enable him to detect the presence of the mite, even when abundant, but the pustules or wheals caused by it are sufficiently described in the paper by Doctors Goldberger and Schamberg and the one by Doctor Rawles to permit of identification. Later, when the gravid female mite (fig. 2) is distended with eggs and young, it is more easily detected; but it is not in this state that it attacks human beings and is thus encountered by the practicing physician.

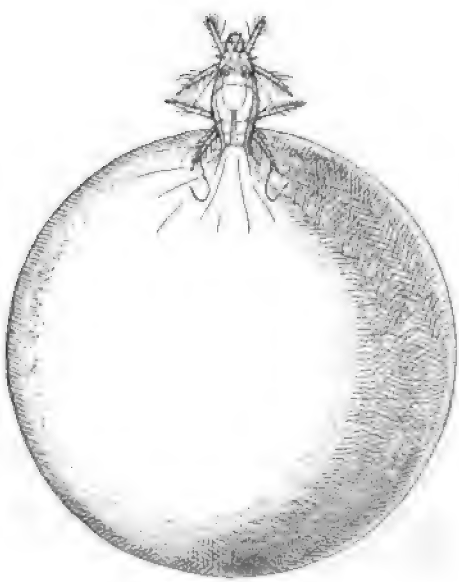

FIG. 2.—Gravid female of *Pediculoides ventricosus*. Greatly enlarged. (Redrawn from Brucker.)

THE MITE BENEFICIAL IN AMERICA.

So far as the author has been able to determine, the first published record of the occurrence of this mite in America was by himself, and was included in a paper printed in the Twelfth Report of the State Entomologist of Illinois (pp. 150–151).[b] While assistant to Dr. S. A. Forbes, state entomologist, he was directed to investigate serious injuries to stored grain by the Angoumois grain moth,

[a] For a consideration of "chiggers," see Circular No. 77, Bur. Ent., pp. 1–6.

[b] Published in Trans. Dept. Agr. Illinois, vol. 20, 1882.

*Sitotroga cerealella* (fig. 3), in southern Illinois, where Messrs. Halliday Brothers, of Cairo, growers and shippers of wheat, were at that time experiencing considerable trouble from the ravages of this grain moth, not only in their grain elevators but also in barges loaded with wheat to be shipped by river to New Orleans and thence exported by steamer.

It was during these investigations that this mite was discovered attacking the larvæ of the grain moth. As the original publication containing the author's observations is becoming more and more difficult to obtain, that portion relating to the occurrence of this mite is given herewith in full:

*Pediculoides* (*Heteropus*) *ventricosus*, Newport. About the 12th of October, 1882, a sack of wheat infested with larvæ of the grain moth was received from southern Illinois, which, for want of time, was put aside for future inspection. On the 13th

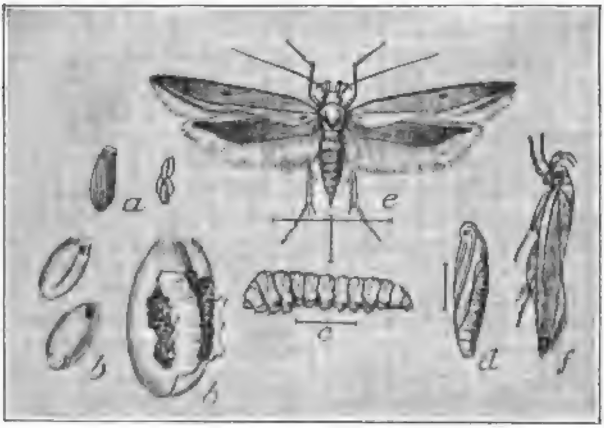


FIG. 3.—Angoumois grain moth (*Sitotroga cerealella*): *a*, Egg and egg-mass; *b*, larva in grain of wheat; *c*, larva; *d*, pupa; *e*, *f*, moth. Enlarged. (*a*, *c–f*, After Chittenden; *b*, original.)

of November, while examining the grains containing larvæ, I noticed, in a lot of fifty, three in which the worms were dead, and on them were numbers of globular, yellow objects, which proved to be a species of mite, *Pediculoides* (*Heteropus*) *ventricosus* Newport. Knowing nothing of the predaceous habits of these mites, and the limited literature at hand throwing little light upon the matter, I did not pay much attention to the fact of their occurrence until the 12th of December, when upon examining 100 grains with respect to the effect of heat on the larva, I found 14 of the latter infested by these mites.

In the meantime I had learned that this mite was known to be of predaceous habit, in both England and France, having been first discovered by Newport, in 1849, in the nests of *Anthophora retusa*, collected at Gravesend, England, and afterwards described by him under its present name. It had also been found in France, in 1868, by Jules Lichtenstein, of Montpellier, and described by him under the name of *Physogaster larvarum*. This gentleman found it in his breeding cages, which it so completely overran that, as he informs me, he could not for six months breed a single specimen of Hymenoptera, of Buprestidæ, or Cerambycidæ, or of some Lepidoptera.

If it has been found by any other persons than these, or in any other parts of the world, previous to its discovery here by me, I have not been able to find the fact recorded.

On December 31 and January 1, I examined 100 infested grains of this wheat, which had been continually kept in the laboratory since it was received, and found 32 per cent of the worms dead, infested by the mites.

While making these examinations I frequently threw the grains containing infested larvæ into a shallow glass dish, where they remained on my table until the warm weather during the latter part of February, when the temperature of the laboratory at night was much higher than it had been during the previous cold weather. The effect of the change was soon plainly to be seen. The contents of the dish began to swarm with newly developed mites, and a larva dropped into their midst was immediately attacked, and after that its life was of short duration. Larvæ placed at some distance from the dish suffered a like infection.

To test the matter I placed near the dish some weeds, in the pith of which some larvæ were hibernating, and in two days the mites had found and destroyed them. These young mites when first noticed are very minute, of elongate form, and extremely active, running about in search of larvæ; and when one is found they immediately puncture the skin and suck the juices.

In a day or two the posterior segments of the abdomen begin to enlarge, and this process continues until the inflated, bladder-like abdomen becomes ten or even twenty times the size of the cephalothorax.

During this time they have gradually lost their ambulatory powers, and remain stationary upon their victims. In the meantime changes equally wonderful have been going on within the abdomen.

Eggs are continually forming, and within these the young mites are as continually developing, passing through their entire metamorphosis, *which includes the acquisition of the fourth pair of legs* (an exceptional character among mites), within the abdomen of the mother, from which they make their way as fast as they reach maturity.

The females are quite prolific. I have counted frequently from 40 to 50 young and eggs within the abdomen, and believe that they produce even more. The mothers survive the birth of a large number, if not a majority, of the young. The male I have never found, and I am inclined to believe with Mr. Newport, that the species is parthenogenous.[a] The minute size of these young mites admits of their free access to the larvæ of the moth, through the very small opening where this made its entry, and a single mite with its progeny would be sufficient to destroy it.

That this is very often the manner of attack is proved by the fact that grains in which the larva is badly infested frequently have no other break in the hull by which even a young mite could gain admission. Like the larvæ on which they subsist, their development is retarded or increased by the temperature, they being quite active at a temperature of 60° F.; but in colder weather able to remain within the abdomen of the parent for months in a dormant state, awaiting a rising temperature.

While, as stated, this was probably the first published record of the occurrence of this Pediculoides in America, the writer has since had reason to believe that it was present many years prior to this date; and, indeed, in the light of information that was obtained during the past year, 1909, it seems altogether probable that it not only occurred but proved noxious to man, in Massachusetts, as early as 1830.

The particular reference, however, to which attention is called may be found in the Prairie Farmer for the year 1845, page 216.

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[a] I have since observed the male, though only occasionally.

Much is here made of larvæ attacking the stems of wheat above the upper joint, and in connection therewith follows this significant sentence: "In one instance nine eggs were found in a single straw, one of which had just hatched." Also, in another journal, we are told that specimens of infested straw were forwarded to the Country Gentleman from Scipioville, N. Y., in 1879, which the sender stated contained eggs, besides larvæ and pupæ. In both cases the larvæ were almost beyond a doubt those of the greater wheat-stem maggot (*Meromyza americana* Fitch). According to my own observation, the mites attack the larvæ of *Meromyza americana* in stems of wheat, and one can not fail to be struck by the clearness with which the statements just given describe larvæ of this species in the stems of grain or grass being attacked by these mites, the gravid female of which has every appearance to the unaided eye of being a minute egg. It therefore seems not improbable that this mite was abroad over the country at the earlier date, 1845, which would antedate by several years the description of the species in England by Newport, who called attention to the occurrence of this mite as a parasite in the nests of a wild bee (*Anthophora retusa* L.) in a paper read March 5, 1850, before the Linnæan Society of London.[a]

In the account given by Dr. T. W. Harris in the second edition of his "Insects Injurious to Vegetation," in connection with his discussion of the early occurrences of the barley jointworm (*Isosoma hordei* Harr.), there are two very significant statements that have until lately puzzled the writer greatly. On page 438, edition of 1852, he says:

> In the summer of 1831, myriads of these flies [meaning the adult *Isosoma*] were found alive in straw beds in Gloucester, the straw having been taken from the fields the year before. An opinion at that time prevailed that the troublesome humors wherewith many persons were then afflicted were occasioned by the bites of these flies; and it is stated that the straw beds of Lexington, being found to be infested with the same insects, were generally burnt.

The second reference occurs on page 440 of the same volume, in which it is stated that "about eight years ago [which would be about 1844] some of these insects [again referring to the barley jointworm] that had come from a straw bed in Cambridge were shown to me. They had proven very troublesome to children sleeping on the bed, their bites or stings being followed by considerable inflammation and irritation, which lasted several days. So numerous were the insects that it was found necessary to empty the bedtick and burn the straw."

Now, to the writer it has always been puzzling that the adults of the barley jointworm, as they were described by Doctor Harris, should have been able to bite through bedticking and cause the

[a] Description published in Trans. Linn. Soc. Lond., vol. 21, p. 95, 1853.

eruption described and yet not be able to gnaw through this cloth and make their escape, as every one who has reared these insects in confinement has witnessed their frantic efforts to escape as soon as they gnaw their way out of the straws. The mite *Pediculoides ventricosus* now furnishes as good an explanation of these attacks referred to by Harris as we can expect to secure, after a lapse of three-quarters of a century, with no possibility of obtaining actual proof in the case.

In 1884 the writer found this same mite attacking and destroying the wheat strawworm (*Isosoma grande* Riley) at Oxford, Ind., and in speaking of the occurrence of this larva and its parasites, he made this statement:

> Curiously enough, during the time it occupies the stubble in the larval and pupal stages, it sometimes falls a victim to the mite *Pediculoides* (*Heteropus*) *ventricosus*, which enters the stubble from above after the grain is cut, but whose sense of discrimination is rather poorly developed, and it is finally victorious over the *Isosoma* larvæ, its parasites, and the predaceous larvæ of *Leptotrachelus dorsalis*.

The same year, and in the same locality, this mite was again encountered by the writer, attacking the greater wheat-stem maggot in wheat straw, and the remarkable resemblance of the gravid females to minute eggs was again noted. Since that time this Pediculoides has been reported by Mr. E. M. Ehrhorn attacking the larvæ of the peach twig borer, *Anarsia lineatella* Zell., in California.[a] The same year Mr. Marlatt reported it as attacking the eggs of the periodical cicada, *Tibicen septendecim* L.[b] The same year Dr. F. H. Chittenden[c] stated that this mite attacked the larvæ of two species of bean weevil (*Bruchus quadrimaculatus* Fab. and *B. chinensis* L.) and destroyed them, often in great numbers. Still later, in 1904, Messrs. W. D. Hunter and W. E. Hinds, in Bulletin No. 45, Division of Entomology, page 107, called attention to its attack on the larvæ of the cotton boll weevil. In 1908 Mr. W. Dwight Pierce[d] stated that this mite is a common weevil parasite in Mexico. In the same publication, page 42, he credited it with being parasitic, not only on the cotton boll weevil, *Anthonomus grandis*, but also on an allied species, the pepper weevil (*A. eugenii* Cano). Dr. A. D. Hopkins informs the writer that in his studies of forest insects he has encountered it attacking the larvæ of wood-boring beetles, and at one time, in West Virginia, it caused considerable mortality in his rearing cages, where he was attempting to rear wood-boring longicorn beetles (Cerambycidæ) and barkbeetles (Scolytidæ), precisely as experienced by M. Jules Lichtenstein in France.

[a] Bul. 10, Div. Ent., U. S. Dept. Agr., p. 17, 1898.

[b] Bul. 14, n. s., Div. Ent., U. S. Dept. Agr., p. 104, 1898.

[c] U. S. Dept. Agr., Yearbook for 1898, p. 247.

[d] Bul. 73, Bur. Ent., U. S. Dept. Agr., p. 30.

In the publication of Messrs. Hunter and Hinds previously referred to, some information is given relative to an attempt to use this mite artificially in overcoming the boll weevil. It has been experimented with quite extensively by Prof. A. L. Herrera and his assistants of the Mexican Commission of Parasitology, and upon his return from a trip to Mexico in the fall of 1902 Mr. Hunter brought with him, through the kindness of Professor Herrera, a supply of the parasites, from which others were reared for experimental work in Texas. This experiment, however, owing to conditions beyond the control of man, appears, fortunately perhaps, not to have resulted satisfactorily. One of the principal obstacles in this case seems to have been that, where the mites succeeded in establishing themselves, they were subsequently destroyed by the attacks of small ants.

These references show quite clearly the wide distribution of this mite throughout the United States and its great variety of host insects. We have, in later years, come to consider it a very useful parasite and one that is likely to attack almost any soft-bodied larva to which it can gain access and be secure from other predaceous insects and adverse meteorological conditions.

## THE MITE PROVES NOXIOUS TO MAN.

As indicated in the earlier portion of this paper, either this or some other closely allied species has long been known to occasionally attack man and animals in Europe, when these are engaged in handling or come into contact with grain or straw infested by their host insects. The first instance of this character to be noted in America, however, has been communicated to the writer by Dr. Henry Skinner, of Philadelphia, Pa. It was about the year 1896, while Doctor Skinner was practicing medicine in Philadelphia, that the owner of a boarding house in one of the New Jersey suburbs of the city came to him in great distress, stating that the tenant and keeper of the boarding house, which accommodated about seventy-five persons, would not pay the rent thereon, and further stated that the tenant had been threatened with legal proceedings by the boarders, who had even suggested bodily injury. The occasion of all this trouble was an epidemic of a rashlike disease, the causes of which were suspected to reside in the mattresses of the beds occupied by the patrons of the house, because the occupants had been attacked by a very mysterious and aggravating skin eruption. The owner submitted straw dust and mattress débris taken from the suspected beds, and on examination of this Doctor Skinner found specimens of this mite. The house was promptly deserted by the boarders, none of whom, as it seems, escaped infection, and none of whom was

willing to return. The matter does not appear to have been further investigated.

In 1901 Jay F. Schamberg, M. D., of Philadelphia,[a] published a short paper calling attention to and describing "An Epidemic of a Peculiar and Unfamiliar Disease of the Skin." In this paper Doctor Schamberg, who, besides being a practicing physician, is professor of dermatology and infectious eruptive diseases in the Philadelphia Polyclinic, described a number of cases that had been treated by him a few weeks prior to the publication of his paper. The eruption and its effect on the patient were briefly described and illustrated, but the causes instrumental in bringing about these attacks were still unknown to him; and, as several members of the same household were commonly affected, the disease was considered likely to prove contagious. The dermatitis, however, was not lost sight of, and in a paper contributed to the Public Health Reports Dr. Joseph Goldberger, passed assistant surgeon of the United States Public Health and Marine-Hospital Service, in cooperation with Doctor Schamberg,[b] published the first exact information we have relative to the cause of these epidemics. This paper, so far as known to the writer, is the

FIG. 4.—Lesions caused by bites of the mite *Pediculoides ventricosus*. In this case the eruptions are excessively large, blister-like, and sparsely placed over the body including the neck, while there are none upon the arms.

[a] Phila. Medical Journal for July 6, 1901.

[b] Public Health Reports, vol. 24, No. 28, July 9, 1909.

first publication in this country in which the attack of this mite has been followed up and its dermatological effect on human beings carefully studied and described. This paper of Doctors Goldberger and Schamberg may be briefly summarized as follows:

In the spring and summer of 1909 this peculiar eruptive disease became quite prevalent in Philadelphia and neighboring towns. An outbreak among 20 sailors upon a private yacht docked in the Delaware River attracted the attention of both the city and the federal health authorities. The Surgeon-General of the United States Public Health and Marine-Hospital Service delegated Dr. Joseph Goldberger, passed assistant surgeon, to proceed to Philadelphia for the purpose of making an investigation of the disease.

FIG. 5.—Lesions caused by bites of the mite *Pediculoides ventricosus*. In this case the eruptions are almost the reverse of those shown in figure 4. They are much smaller, more densely placed, and confined more to the lower portion of the back, there still being very few on either neck or arms.

After examining the 20 sailors, who had been sent to a hospital, Doctors Goldberger and Schamberg visited the yacht whence they came and made a searching examination of the conditions on board. Their attention was directed to the fact that a number of new straw mattresses had been received and that the disease was confined to those who had slept upon these mattresses or had placed their clothes upon them. Eleven officers and members of the crew who did not sleep upon the new mattresses remained entirely free of the disease.

At about the same period information was received concerning an eruptive disease prevailing among the sailors of four other boats, plying along the Delaware River. Investigation disclosed the fact that these boats had also received new straw mattresses, and, furthermore, that only those were attacked who slept upon the mattresses or otherwise came in contact with them.

In addition to these cases among sailors, Doctors Goldberger and Schamberg examined or received authentic information concerning seventy other cases of this disease occurring in twenty different households in Philadelphia and its vicinity.

In practically every instance they were enabled to determine that the patient had either recently slept upon a new straw mattress or had freely handled the same. Where only one person in a household was affected, it was found that he was the only one to occupy a bed supplied with a new straw mattress. They were able to trace all of the incriminated mattresses to four leading mattress manufacturers. Figures 4, 5, 6, and 7, from photographs by Doctor Schamberg, show the condition of some of the victims and illustrate different forms of the eruption.

FIG. 6.—Lesions caused by bites of the mite *Pediculoides ventricosus*. In this figure the eruptions are still more minute, covering the entire body, including the arms and neck, the hair having been removed from the neck to show their diffusion even on the base of the head. The lesions are also less swollen than shown in figure 5.

Careful investigation warranted them in excluding from consideration the ticking of the mattresses and the jute or cotton topping contained therein. The cause of the disease was, therefore, circumscribed to the straw. Repeated inquiries elicited the information that all of the manufacturers had received, at the time the disease-producing mattresses were made up, wheat straw from a dealer in Salem County, in southern New Jersey. One manufacturer had used straw from this source exclusively in the affected mattresses, while in another case the straw had come from southern Indiana.

*Finding of a parasite.*—Doctors Goldberger and Schamberg sifted the straw from a mattress through the meshes of a fine flour sieve upon a large piece of plate glass covered with white paper. Close scrutiny of the siftings under strong electric illumination soon detected some slight motion. The moving particles were touched with

a needle moistened in glycerine and transferred to a glass slide. Search with the microscope disclosed the presence of a mite of very minute dimensions. The mite was identified for them by Mr. Nathan Banks, expert in Acarina of the Bureau of Entomology, United States Department of Agriculture, as very close to, if not identical with, the *Pediculoides ventricosus.*

In order to demonstrate experimentally the etiological relationship of the suspected straw mattresses, Doctor Goldberger exposed his bared left arm and shoulder for one hour between two mattresses. At the end of about sixteen hours, a number of characteristic lesions appeared upon the arm, shoulder, and chest. Later, three volunteers slept upon the mattresses and each one developed the eruption at the end of about the same period.

FIG. 7.—Lesions caused by bites of the mite *Pediculoides ventricosus.* In this case the effect is entirely different from that shown in any of the other figures, the lesions not only covering the body, including the arms, but extending over the face and forehead; they are more sparsely placed but accompanied by very large, irregular, inflamed patches. This figure illustrates the liability of this dermatitis being mistaken for other dangerous, contagious diseases, like smallpox and spotted fever.

Doctor Goldberger later took some of the sifted straw, divided it into two portions, and placed it in two clean Petri glass dishes. One of these was applied for one hour to the left axilla of a volunteer. At the end of from sixteen to seventeen hours the characteristic eruption was present in the area of the left axilla to which the Petri dish of straw siftings had been applied.

The second portion of the straw siftings in a Petri dish was exposed to the vapor of chloroform under a bell jar with a view to killing any insect or acarine that might be present. These siftings were then applied to the right axilla of the same volunteer to whose left axilla the untreated siftings had been applied. The chloroform evidently destroyed in the siftings the agent that was producing the eruption, for no lesions appeared after the application of the chloroformized siftings.

Doctor Goldberger, further, removed from some straw siftings five minute mites, and, placing them in a clean watch crystal, applied the crystal to the axilla of another volunteer. At the end of about sixteen hours following this application five of the characteristic lesions appeared on the area to which the mites had been applied. (See fig. 8, from drawing by L. H. Wilder.)

### INFLUENCES CONTROLLING THE EXCESSIVE ABUNDANCE OF PEDICULOIDES.

It will be noticed that Doctors Goldberger and Schamberg made no attempt to discover the underlying causes for the enormous numbers of these mites inhabiting the mattresses involved in their investigations, that problem coming properly within the realm of entomology. When the writer took up this subject with the view of finding out the causes for such an abundance of these mites, Doctors Goldberger and Schamberg very kindly placed at his disposal everything in their possession relating to this epidemic, including the mattress which Doctor Goldberger had himself used in experiments with this mite, carried out by him at the Hygienic Laboratory in Washington. Doctor Schamberg was equally kind in placing at his service all of the material, notes, and photographs in his possession.

FIG. 8.—Lesions caused by bites of the mite *Pediculoides ventricosus*. About natural size.

Almost at the commencement of the investigation, Dr. William Royal Stokes, of the Maryland state board of health, informed the writer that a similar but less extensive epidemic had shortly before been noted in Baltimore. This he kindly described as follows:

> The matter was brought to my attention by several persons, who came to the head of the department and complained of the skin eruption described. They stated that a number of people in a suburban hotel were similarly affected, but I do not remember the number at this late date. These persons volunteered the information that they had all been sleeping on some new straw mattresses, and that all of the persons similarly affected had used these mattresses.

I saw Doctor Gilchrist, the clinical professor of dermatology at Johns Hopkins University, yesterday, and he gave me the following description of the one case which he saw at the health department. I saw two other cases which corresponded with these in a general way.

"The eruption consisted of about 1,000 wheals, or erythemato-withicarial spots, or papulo-withicarial lesions. As in the description in the reprint of Doctors Goldberger and Schamberg, of the United States Public Health and Marine-Hospital Service, they varied in size from a lentil seed to a finger nail, and are round, oval, or irregular in shape. No vesicles or pustules were seen. The eruption was on the neck, chest, abdomen, and back, and also on arms and legs. Itching was present, and all lesions showed evidences of scratching."

Besides this, there were several cases reported to the writer from northern Maryland, where farmers in running their wheat through a fanning mill had been simultaneously troubled by a very similar or identical eruptive disease of the skin. In another instance, a thrasherman engaged in feeding the unthrashed grain into the cylinder of

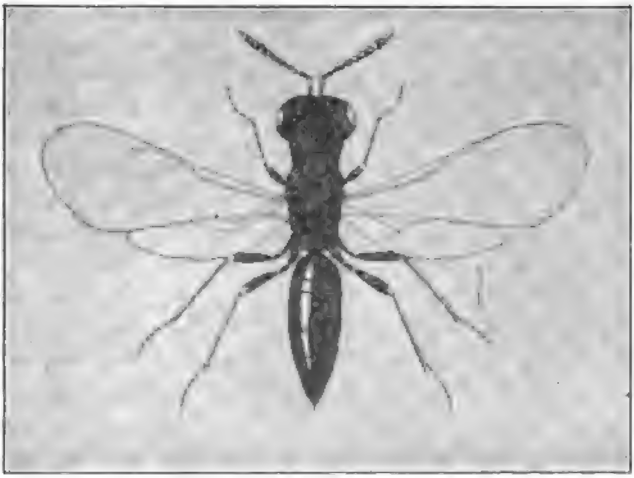

FIG. 9.—Adult of jointworm (*Isosoma tritici*). Much enlarged. (From Howard.)

the thrashing machine was also affected by a disease of the skin, entirely unfamiliar to the attending physician, who could not classify it with any urticaroid dermatitis known to him. After the writer's experience of previous years, it seemed impossible that this Pediculoides should become sufficiently abundant to cause this dermatitis without there being an excessive abundance of some host insect or insects affecting either the straw or the grain itself. Naturally, the studies made by him in 1882 led him to suspect that the Angoumois grain moth (*Sitotroga cerealella*) might be responsible for the abundance of the mites. Then, too, the fact that it attacked the wheat-straw worm (*Isosoma grande* Riley) in wheat straw led him to suspect that, as this particular species is not known to occur in the vicinity of Philadelphia, while its near relative, the joint worm (*Isosoma tritici* Fitch) (fig. 9), does occur more or less abundantly over the

eastern part of the country, this latter species, too, might perhaps be involved.

With a view to finding out something of the abundance of the grain moth in New Jersey, from which State was obtained most but not all of the straw entering into the mattresses mentioned by Doctors Goldberger and Schamberg, the writer applied to Dr. John B. Smith, state entomologist, for information. In reply Doctor Smith was kind enough to send the writer an advance copy of the report of his department of the New Jersey Agricultural Experiment Station for the year 1908, and from this publication it was learned that during the summer of that year, owing to favorable weather conditions, this moth developed rapidly in the field and there was great damage to wheat among those farmers who delayed thrashing until September or later. Furthermore, a very large percentage of the wheat crop gathered that year became useless for milling purposes, and so general was the infestation that grain from some localities was entirely barred at mills except when ground for the owner. Some further investigations carried on in eastern Pennsylvania revealed a very similar condition of affairs. It was the straw of 1908, coming mostly from New Jersey, but a small part of it from Indiana, that entered into the mattresses, from the use of which came the epidemic in and about Philadelphia.

In order to settle these points, Mr. V. L. Wildermuth, of the Bureau of Entomology, was instructed to examine the straw in the mattress placed at the writer's disposal by Doctor Goldberger. After a day and a half of careful search, only five straws affected by the joint-worm were found. This seemed to entirely eliminate this species from consideration in connection with this particular epidemic. There were, however, many wheat heads remaining attached to the straw, and these heads contained a great many kernels, the contents of which had been eaten out by the larvæ of the grain moth. Moreover, these eaten kernels contained great numbers of the dead bodies of Pediculoides. That the Angoumois grain moth was the cause of this damage to the wheat was still further proved by the emergence of an adult moth from these eaten kernels on November 15. The larvæ of this moth infested the kernels of wheat before the latter were thrashed. Many of these infested kernels remaining in the straw were included in the material going into the manufacture of these mattresses. The greater portion of the living larvæ of the moth would develop to adults during May or early June, thus cutting off the food supply of these mites. The mites would therefore very naturally swarm among the straw and, making their way through the cloth covering of these mattresses, attack anything that gave promise of furnishing food and preserving them from starvation. It seems that starvation is the final outcome, however, for, as already

stated, no trouble is experienced in using the mattresses after a certain period, which period probably indicates the termination of the life of the mites infesting the straw. It therefore did not seem necessary to seek further for the primary cause of this eastern epidemic of dermatitis, the center of which seems to have been in and about Philadelphia.

### A WESTERN EPIDEMIC OF THE DERMATITIS.

While the problem of the epidemic in the East was apparently solved, some of the wheat straw involved therein had come from Indiana, and during the last few years an outbreak of the jointworm (figs. 10 and 11) had been gathering force throughout Ohio, Indiana, and southern Illinois, until during the summer of 1908 very serious damages occurred. Investigation of the insect during previous years had shown that the outbreak really began in the more elevated portions of Virginia, in the upper Shenandoah Valley, in West Virginia, and in eastern Ohio, as early as 1904, afterwards advancing broadly to the westward.

FIG. 10.—Effect of jointworm attack on wheat straw in field. Note enlargements and distortions. Reduced. (Original.)

During the summer of 1908 there came to the Bureau of Entomology from this section of the country a great number of complaints of serious skin trouble among people engaged in thrashing grain that had been stored for some time in barns, and in some localities it had become difficult to secure help to thrash under such conditions. Also the same disorder was encountered by those who used this straw for the purpose of filling bedticks, or as a substitute for felting under carpets, and in one case berry pickers had been attacked when such straw had been used as a mulch for berry plants. This straw came from a field that had been seriously damaged from jointworm attack in 1908. In one instance a carload of wheat straw was shipped to Pittsburg, Pa., and six men engaged in unloading it were attacked

by some skin eruption, and the horses used in hauling this straw after it was unloaded also suffered from what was seemingly the same disorder. Perhaps the following from a correspondent of the Bureau of Entomology, residing in southern Ohio, will give a fair idea of the situation on many farms in that section of the country:

About four years ago a parasite was found when thrashing wheat out of barns. It seemed to affect the victims almost as soon as they got into the mow. The men began to scratch themselves, generally on the neck and on the arms (inside) opposite the elbow, and on the body, back and front. The parasites raised welts such as you describe and spread as you indicate. They have spread to such an extent that farm hands dread them and will not change work with neighbors unless they thrash in the field. Here of late they are found in wheat straw in the barns, especially if baled. Last week a farmer brought me baled wheat straw that seemed to be alive with them. They attacked every one that went into the barn, and one of my horses that was perspiring from effects of a drive was simply covered with little knots or swollen places and bit and rubbed himself continually. I had to have the straw hauled out and burned and the barn disinfected. The farmer stated that they were so thick in the shed that contained the straw that he had to keep all stock out of the shed.

FIG. 11.—Female Isosoma in act of depositing egg in stem. About life size. (Author's illustration.)

Many other similar letters from towns in Ohio were received by Doctor Schamberg, particularly from Zanesville, Columbus, Vincent, Springfield, etc., where the affection is popularly believed to be due to "chiggers." A physician from the last-named town stated that in the fall of 1908 during harvest and thrashing time he saw in Washington County some 87 cases of the disease in question. It affected the harvesters and thrashers. This spring he observed 38 cases from contact with straw ticks refilled with straw of last fall's crop. The disease is said to have been more prevalent last year (1908) than ever before. Information has come from Columbus, Ohio, that potters who used straw for packing crockery ware have been so badly attacked at times that the entire force of packers has been off duty. Many

times a whole carload of straw has been so affected that the use of it has been abandoned. In Springfield, Ohio, it is said that the disease was so bad a year or two ago in the lowlands west of the city as seriously to hamper the progress of the construction of a large sewer; this, however, might have been due to attack by other mites. In Zanesville, Ohio, the potters have been obliged to abandon the use of straw and employ "prairie hay" for packing purposes.

Doctor Schamberg was also informed by a physician of Pittsburg that a young woman patient had suffered from an affection closely resembling if not identical with the one under consideration each time that she had assisted in emptying cases of dishes packed in straw. Both the physician and the patient had come to believe that something in the straw was the cause of the eruption.

Indeed, so nearly did the territory from which these complaints came to us coincide with that affected by the jointworm that it created the suspicion, not only among those engaged in the investigations, but even among farmers themselves, that there must be some connection between the two phenomena. Very many of these cases were brought to the notice of practicing physicians, but the latter were at a loss to account for the prevalence of this dermatitis, many of them supposing it to be some species of rash that was more or less contagious, the exact nature of which they did not know. The liability of confusion with other vastly more serious contagious diseases, notably smallpox, was of course very great.

Among these physicians was Dr. Lyman T. Rawles, of Huntertown, Ind., who, in May, 1909, undertook a careful study of a number of cases of this dermatitis that had come under his personal observation, as well as those of some of his associates. Doctor Rawles's investigations were very carefully made, and the results are exceedingly valuable for the reason that, in the case of this western epidemic, he was able to trace the cause of the skin eruption to the mite (*Pediculoides ventricosus*) and follow this back to the host insect, the wheat jointworm (*Isosoma tritici*).[a] It clears up the obscurity surrounding the cause of this epidemic in the Middle West, a section throughout which the Angoumois grain moth never occurs in excessive abundance excepting in grain that is kept in store, and then only in the more southern portion of Indiana and Illinois.

In May, 1909, Doctor Rawles found in his practice that a very strikingly strange skin disease presented itself in his own and the

[a] Owing to an unfortunate misunderstanding, for which no one connected with these investigations is responsible, Doctor Rawles did not receive a proper determination of the mite involved in his studies of the dermatitis. The entomological nomenclature in his paper, printed in the Journal of the Indiana State Medical Association, August, 1909, should therefore be corrected by substituting *Pediculoides ventricosus* for *Ditropinotus aureoviridis* wherever the latter name occurs.—F. M. W.

surrounding country in epidemic form. Through the press notes it seemed to be quite general over the northern part of the United States, limiting itself to the wheat-growing sections.

The people generally affected were farmers and those living in small villages or towns where straw is used in beds, under carpets, and around stables to bed stock. Horses and cattle have been seen with a skin disease almost identical with that seen in man. The following incident led him to an investigation as to the probable etiology:

A family had cleaned house, refilled the straw ticks of their beds, and placed fresh straw under the carpets, and in about one week the family had developed this peculiar skin disease. In the beds was found a small black fly (*Isosoma tritici* Fitch) about the size of an ordinary gnat, which at first it appeared to be, but closer observation revealed that it was not of the gnat family. Upon examination of the straw it was found that a large number of the straws were perforated; these perforations were through the wall in the region of the joint, generally about 2 inches from the joint. The perforations were about the size of a small pinhole and ranging in number from ten to thirty in a straw. Upon examining a section of this straw the small black fly was found under many of the openings through the walls.

Several flies were examined to ascertain if they possessed a piercing proboscis, and while observing one which had just been taken from under the sheath of the straw, through which there was no perforation over the fly, a small mite was observed crawling over the dead body of the fly.

Placing the bodies of several of these flies under the microscope and using a one-fourth-inch objective and a No. 5 eyepiece, it was found that on nearly all flies over which the wall was intact a small mite could be detected, these varying in number from two to four mites to each fly. Upon furthering the observations it was found that the dermatitis lasted after the flies had been observed and exterminated.

The following experiments were tried to prove whether it was the fly or the mite that was the etiologic factor in producing the dermatitis.

Six live flies were taken, upon which no mites could be found; these were placed under a watch glass and bound upon the right arm, leaving them in contact with the skin for three hours. Upon the left arm four dead flies, on which living mites had been observed, were placed under a watch glass and left in contact with the skin for three hours, after which the glasses were removed and results awaited. The right arm showed nothing. Upon the left arm there appeared within twelve hours four small wheals, the character and evolution of which are later described.

To further the experiments some fresh lesions of patients were scraped and the scrapings examined microscopically, and two of the mites were found in the scrapings.

Itching is the most prevalent and first symptom to attract the attention of the patient. It is most persistent and intense during the after part of the night. At about the time the itching was most intense there appeared an urticarial eruption, accompanied, in severe cases, with general systemic symptoms, such as rise of temperature from 99 to 102; in one case the temperature rose to 103.8; the pulse rate is accelerated to 100, or as high as 110—in one case to 130. Other symptoms were intense headache, anorexia, nausea, in some cases vomiting, and a mild form of diarrhea. In severe cases some complained of general joint pains and backache; in these cases the urine was examined and albumin in small amount was found, but no casts or blood. When the acute symptoms disappeared, so did the albumin.

Many patients who suffered from mild cases complained of nothing aside from the intense itching. If all straw was removed from the beds and house, the symptoms would subside in one or two days and completely disappear in a few days more.

The lesion, which is typical of the disease, is the urticaria vesiculosa. The urticarial lesion varies in size from that of a split pea to that of a penny; it is surrounded by a pinkish halo, varying in intensity of color from a pale pink to a most bright pink. The "hive"-like lesion is at first blanched, but later becomes a rose-red color. It is elevated about 1 or 2 millimeters above the skin surface, and is surmounted by a small vesicle containing a whitish fluid marking the place of inoculation. The vesicle is about 1 or 2 millimeters in diameter and elevated about 3 millimeters above the surface of the urticarial lesion. As the lesion grows old it goes through the process of evolution: (1) It is blanched and has a central vesicle; (2) it is rose-red and the vesicle may become a pustule; (3) it generally recedes to the skin level with scab formation, due to the scratching; (4) it leaves a brownish or greenish-yellow or purple spot on the skin surface. In debilitated patients the markings look not unlike faded indelible-pencil marks. (This was noted in a patient suffering from pulmonary tuberculosis.) These discolorations may last for several weeks.

The anatomical location of the lesions is generally the back, sides, and abdomen, and less frequently the arms and legs. The neck has very few lesions; the face, hands, and feet have very few or none.

The number of lesions depends upon the number of mites, ranging from very few to thousands; in some cases the back and abdomen have been almost a solid mass of lesions—new lesions on the tops of old lesions, so having lesions in all stages of development.

Later investigations carried out by Mr. Wildermuth, at Lafayette, Ind., during December, 1909, and January and February, 1910, show that where straw is kept in masses, as in stacks and barns, the mites literally swarm through the straw, and as soon as an Isosoma or its parasites attempt to gnaw their way out through the cells in the

straw, the mites enter and kill them before they are able to enlarge the opening sufficiently to enable them to make their escape; indeed, not more than 5 per cent succeeded in escaping.

As this represents fairly well the conditions of straw in spring and early summer when it is used for the manufacture of mattresses and on the farms for the filling of straw ticks and as a substitute for felting under carpets, the great number of cases of this dermatitis occurring over the country is not at all surprising, and the indications for the season of 1910 are more favorable for an increase than a decrease in the trouble.

OBSCURITY SURROUNDING THE OCCURRENCE OF THIS SKIN DISEASE.

The exact nature of this eruptive disease was not at all understood by the medical profession throughout the country. In southwestern Virginia thrashermen suffered from the same disorder, but attributed it to "chiggers" (fig. 12), and local physicians, though skeptical, were themselves unable to correctly diagnose or to account for the trouble. As the disease is not serious and passes away in the course of time without leaving the patient in any way permanently injured, it seems to have been passed over by medical men without investigation, excepting by the physicians whose publications have just been cited. Among the people themselves the eruption was probably more frequently attributed to attacks of "chiggers" or a "rash" than to any other cause, and it is quite likely that this common erroneous interpretation of the origin of the eruption has prevailed generally throughout the country, including the upper Shenandoah Valley in Virginia, where the jointworm was abundant as far back as 1904. It was, consequently, rather unfortunate that, with the beginning of this disorder, an institution in one of the States involved should publish a newspaper bulletin crediting the epidemics of this eruption to the attack of "chiggers," and, furthermore, that a second press bulletin, accentuating the first, should have been issued and sent to every newspaper in the State and from these copied into other newspapers throughout the country. Thus it was that an entirely erroneous impression was magnified and still further diffused.

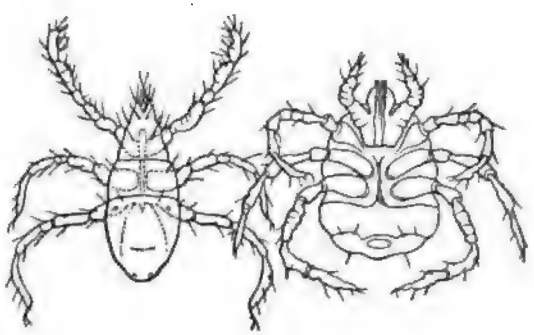

FIG. 12.—*Leptus americanus* at left; *Leptus irritans* at right. Highly magnified. (After Riley.)

In order to determine the likelihood that those handling straw in the wheat field will be attacked by the small red mites often mistaken for "chiggers" that abound in the harvested grain at this time,

Mr. Wildermuth, of the Bureau of Entomology, made a number of experiments. In no case was he able to provoke an attack from theso red mites, probably *Tydeus* sp., even when they were confined upon tho skin of his bare arm. On the other hand, examinations of straw from various points in Ohio and Indiana have revealed the presonco of Pediculoides in the cells occupied by the jointworm. This seems to entirely eliminate "chiggers" from these investigations because these were probably not present and there does not longer appear to be any doubt that *Pediculoides ventricosus* is to be charged with causing the epidemic of this dermatitis. The cause of its own excessive abundance lies in the outbreaks of the Angoumois grain moth upon the grain in the East and the jointworm in the wheat straw in the Middle West. Therefore "chiggers" do not appear to figure as a cause in such epidemics.

### LIGHT THROWN UPON OTHER PROBLEMS.

These investigations have illustrated very nicely the extent to which the solution of one entomological problem will at the same time also solve other problems more or less closely allied to the original one. The light thrown upon the cases of eruption noted by Doctor Harris in connection with the barley jointworm has already been explained. The present outbreak of the jointworm in the Ohio Valley probably originated in the upper Shenandoah Valley of Virginia, extending northward and westward throughout West Virginia and eastern Ohio. When investigation of the insect was taken up in 1904 a parasite, *Ditropinotus aureoviridis* Crawford, was also noted in excessive abundance, but for some reason it did not overcome the jointworm. This phenomenon has been noted continually. Since that time it has been a perpetual enigma to the writer why it was that with such an abundance of its natural enemies the jointworm should continue to spread and increase in destructiveness. Now, however, that we know that this predaceous mite is able to develop through a series of years in such immense numbers in connection with the jointworm, the matter comes nearer a solution. Ditropinotus, as well as some other parasitic enemies of the jointworm, emerge in early July from eggs that were previously placed in the cells occupied by the jointworm. As soon as the adult parasites emerge they at once oviposit in cells containing jointworm larvæ of the same generation from which they themselves developed. The puncturing of these cells by the ovipositor of these parasites, particularly Ditropinotus, opens a way for the entrance of this microscopic mite, and, once inside of the cell, it will destroy everything therein, whether it be jointworm or parasite. Thus the predaceous mite has prevented the other parasites from controlling the jointworm because it has continually checked the increase of other parasites.

In the light of the foregoing, it would appear that the only way to evade the disorder among human beings caused by this mite lies in preventing the occurrence of these two destructive grain insects which are responsible for the abundance of the mite itself. There is, therefore, a double incentive for the farmer to use every effort to prevent the occurrence of these pests in his fields. In many fields in Ohio Mr. Wildermuth found that more than one-half of the straws had been attacked by jointworms, and the damage resulting from their attacks amounted to a considerable percentage of the farmers' wheat crop. (See fig. 13.) In addition to this—and we now know that this mite is generally present—his own family and employees suffer the annoyance of this dermatitis and also those who attempt to use mattresses into which the infested straw has entered. Thus people hundreds of miles away, unaware of the presence of these mites in mattresses, are caused not only great aggravation but intense suffering through their use.

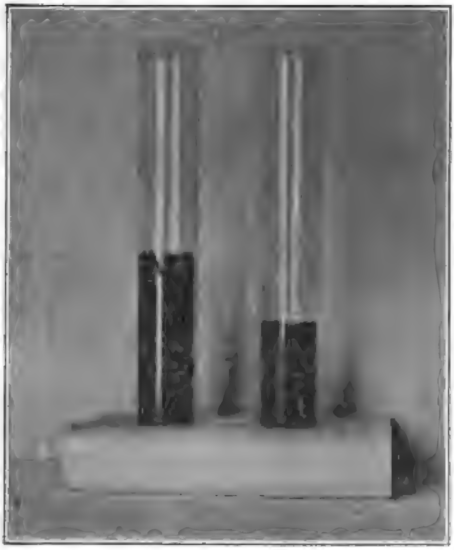

FIG. 13.—Reduction in yield of wheat attacked by jointworm (*Isosoma tritici*). The tube at left contains yield from 100 heads from uninfested straws; tube at right contains yield from 100 heads from infested straws. (Original.)

### DEVELOPMENT OF THE MITES.

The investigations carried out during the winter of 1909–1910 by Mr. Wildermuth reveal the fact that a period of from six to an indefinite number of days elapses between the time a female emerges from the abdomen of the mother until it produces young. This depends upon temperature.

For a temperature of from 90° to 100° F., six days elapses; for a temperature of from 80° to 90° F., seven days elapses; for a temperature of from 70° to 80° F., nine days elapses; for a temperature of from 60° to 70° F., thirteen days elapses, and for a temperature of from 50° to 60° F., twenty-eight days elapses.

With temperatures lower than 50° F. it is doubtful if the mites would develop. The periods required for the development of different females subjected to the same temperature are very uniform. (For instance, in temperatures of from 70° to 80° F. nearly every female produced young in exactly nine days.) The life of the mites

varied from eighteen to an indefinite number of days—forty-three days was the maximum age for those kept under the lower temperatures. The number of young produced by a single female varied considerably and variation was greater among individuals under like conditions than among those under variable conditions. The number varied from just a few to 270. From 3 to 8 males were usually produced, there being two exceptions to this: In one instance, when the temperature was between 70° and 80° F., 26 males were produced and in another case a large number. The firstborn in many cases were males. The largest number of young produced during any one day by a single female was 52.

The ideal temperature for rapid development and the production of the maximum number of young was from 70° to 80° F. The abdomen of the female reaches its maximum size in about five days. The mite is omnivorous, preferring smooth larvæ to hairy ones. A young mite can not enter a closed Isosoma cell. Mites can live only a short time without food—less than a day in all cases observed. Copulation occupies only a few minutes, the males rarely leaving the surface of the abdomen of their mother. In the laboratory a single Isosoma pupa or larva will sustain a female up to the time she produces young and continue to support her progeny for from twenty to twenty-eight days. In the field, or under natural conditions, one pupa would probably furnish food for live mites for approximately the same length of time, as in one experiment a pupa furnished sufficient food for a month. The mites can be kept alive by subjecting them to a low temperature and development checked for an indefinite time. When attacking human beings they do not bury themselves in the skin and remain there as do the "chiggers."

## PREVENTIVE AND PROTECTIVE MEASURES.

Throughout the territory involved in the eastern epidemic of this dermatitis, which was due to the excessive abundance of the Angoumois grain moth, the evidence recently obtained by the writer has been overwhelmingly to the effect that where wheat was thrashed as promptly as possible after harvest and directly from the shocks in the field, almost no occurrence of this grain moth, without which there would be no mites, was observed by millers and others handling the thrashed grain. On the other hand, when hauled from the field and placed unthrashed in the barn, the damage from this pest has varied up to nearly 50 per cent, and has so affected the crop as to cause its rejection by millers, except where ground on the farmer's order. Here, then, is a means of protection for people who use or handle wheat straw grown in this section of the country.

In Ohio, Indiana, and Illinois, where the mite causing this dermatitis has increased enormously on account of the prevalence of the

jointworm, wheat placed in the barn before thrashing has been found much more likely to produce epidemics of this disorder, although the difference between wheat thrashed in the field and in the barn is not so striking as where the trouble results from abundance of the grain moth.

A careful study of a large number of wheat fields in central Ohio by the Bureau of Entomology has shown that the infestation from the jointworm during the season of 1909 varied from 1 to 95 per cent. Here, too, the mite was found generally in the cells in the straw occupied by the jointworm larvæ. It has been found that in central Ohio September sown wheat is much more seriously affected by the jointworm than that sown in October, and also that the infestation is worse in both cases on poor soil than on that of an average degree of fertility, and still less on good soil. The infestation is invariably worse in fields on which wheat had been grown the previous year, and in fields lying adjacent thereto. Fall-plowed fields showed the least infestation of all. It appears, therefore, that moderately late-sown wheat on good soil and on land not devoted to wheat the previous year nor lying adjacent to such fields, escapes with the least injury, and that less difficulty with the dermatitis is experienced where wheat has been thrashed from the field and as soon as possible after the grain was harvested. As the jointworm winters over in the stubble, where this can be burned during fall, winter, or spring, the destruction of both the pest and the mite in the field will be complete. Where this can not be done, much good may be accomplished by raking over last year's stubble fields in the spring and burning the stubble thus collected. So important are these measures that practicing physicians might almost include them with their prescriptions for this painful skin disorder.

### SUGGESTION TO CORRESPONDENTS.

In order that this mite may be further studied with reference to its direct relation to man, all requests for information and correspondence relating to dermatological matters should be addressed to Dr. Joseph Goldberger, passed assistant surgeon, United States Public Health and Marine-Hospital Service, Hygienic Laboratory, Washington, D. C. All correspondence relating to entomological and agricultural matters connected with epidemics of this skin eruption should be addressed to the Bureau of Entomology, Department of Agriculture, Washington, D. C.

Approved.

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *January 11, 1910.*



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BUREAU OF ENTOMOLOGY—CIRCULAR No. 119.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE CLOVER ROOT-BORER.

BY

F. M. WEBSTER,

*In Charge of Cereal and Forage Insect Investigations.*

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1910

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Cereal and Forage Insect Investigations.

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# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE CLOVER ROOT-BORER.

(*Hylastinus obscurus* Marsham.)

By F. M. WEBSTER,

*In Charge of Cereal and Forage Insect Investigations.*

### INTRODUCTION.

The clover root-borer (*Hylastinus obscurus* Marsham) is not a native of America, but has been introduced from Europe and has established itself in the fields of red clover in some sections of the eastern United States, as well as throughout the States of Oregon and Washington, wherever clover is grown. It frequently commits serious depredations by burrowing in the roots, thereby destroying the plants. It has long been known in Europe as a clover pest, Eichoff[a] giving its distribution as Germany, Austria, France, England, and the Canary Islands. Other European entomologists have also written of its occurrence, and, according to Bach, it infested large fields of clover near Odenbach, Germany, in 1803, an occurrence evidently coincident with its description by Marsham in 1802.

FIG. 1.—The clover root-borer (*Hylastinus obscurus*): Adult insect. Natural size at right. (Author's illustration.)

While it did not come to notice in America as a pest until about 1878, when it was found in destructive abundance in central New York, it probably occurred in this country long prior to that date. Dr. A. D. Hopkins, who is making a special study of this group of beetles, viz, the Scolytidæ, has shown the writer a specimen, from the collection of the late Doctor Fitch, with a New York label attached to the pin, referring to a note which he has been unable to find. In all probability, however, this specimen antedates the discovery of the insect by Riley in 1878. Besides, owing to the obscure habits of the pest, it is more than likely that it was injurious to clover even prior to this date without, however, having been detected by farmers. Even at present, both in the Middle West and on the Pacific coast, where it is most destructive, it has attracted little attention, the effects of its ravages being usually

[a] Die Europäischen Borkenkäfer, p. 97, 1881.

attributed to adverse meteorological conditions. The pest seems to have spread much more rapidly westward than southward, as it probably occurs in the East nearly to the Mississippi River; but it has attracted no attention along the Atlantic coast south of Pennsylvania. In that State, however, the writer found it abundant around Chambersburg, but not disastrously so, in October, 1905. It has not been reported at all from the vicinity of Washington, D. C. It is certainly not seriously injurious in the New England States at the present time, the late Dr. James Fletcher reported a similar state of affairs in Ontario, Canada, and we do not receive any reports of its occurrence between the Mississippi River and the Rocky Mountains. In Ohio, West Virginia, Indiana, and southern Michigan it is becoming more and more destructive.

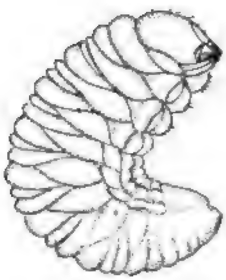

FIG. 2.—The clover root-borer: Larva or grub. Much enlarged. (Author's illustration.)

DESCRIPTION OF THE INSECT.

The fully developed insect is a small, dark-brown, hard-bodied beetle, shown enlarged in figure 1.

The larva, or grub, shown enlarged in figure 2, is about an eighth of an inch long, dingy white, with honey-yellow head and brown jaws.

The pupa (fig. 3) is even smaller than the larva, also dingy white, with two minute spinous projections on the top of the head and two somewhat larger ones at the anal extremity. The eggs are elliptical, white, and minute, yet large enough to be seen with the unaided eye.

LIFE HISTORY.

In the East there is certainly but one generation annually, though this appears to be long drawn out, and scattering individual larvæ and pupæ may be found throughout every month of the year. The finding of eggs as late as September 18 has been reported from Michigan. As a rule, however, the insects pass the winter in the adult stage (fig. 1) within the roots where they developed. During May they abandon the old roots and seek out fresh plants or fields in which to lay their eggs. The eggs are mostly deposited between the middle of May and June 20. The female gouges out a shallow cavity, more often in the crown of the plant, sometimes at the sides of the root even 2 or 3 inches below the crown, and in this places, singly, but not far separated, about half a dozen pale whitish, elliptical, very minute eggs. These hatch in about a week, and the larvæ (fig. 2) for a time

FIG. 3.—The clover root - borer: Pupa. Much enlarged. (Author's illustration.)

feed in the excavation made by the mother, but soon burrow downward into the root, and before the 1st of August the majority of them have become fully grown and passed into the pupal stage (fig. 3). By October nearly all have become fully developed beetles, but they make no attempt to leave the plant until the following spring. Bach states that the adults fly at Omegnen in March and April, while Eichhoff has observed them near Mülhausen, swarming during the warm afternoons about the middle of June; but these observations were all made in different parts of Europe. In our own country, in Ohio, the adults are abroad and have been swept from clover fields early in May; but no swarming of the beetles has been observed, though it is clear that they may migrate about that time of the year.

Fig. 4.—Clover root, showing work of clover root-borer. Slightly enlarged. (Author's illustration.)

### FOOD PLANTS.

In Europe, besides red clover and alfalfa, the species is known to attack Scotch broom, *Cytisus* (*Spartium*) *scoparius*, and goat root or yellow-flowered rest-harrow (*Ononis natrix*). In America it has so far been especially destructive to red clover (*Trifolium pratense*), yet with the recently increasing interest in the growing of alfalfa (*Medicago sativa*) in the Northern States it may be expected to become destructive to that crop also. Besides, it is known to attack mammoth clover (*Trifolium medium*) and alsike (*T. hybridum*). The fact that it also injures the garden pea will be very suggestive to growers of peas for canneries, and indicates the undesirability of sowing peas early in the season on ground that has recently been in these clovers or lying adjacent to the infested clover fields. Late-sown peas, however, would probably not become sufficiently large to invite attack until after the beetles had appeared and gone.

### METHOD OF ATTACKING RED CLOVER.

The insect's method of attack is well illustrated by figure 4, showing a clover root split in two, exposing the excavations. In cases of extreme abundance, however, almost the entire main root, except the bark, is eaten, the substance being displaced by

excreta, and the dead top either becomes detached of itself or is easily broken off if one attempts to pull up the plant. It will be observed at once that until the roots have attained sufficient dimensions it will be impossible for the insect to attack them. Over the territory where red clover is grown in this country the seed is sown either during late winter or spring; and during the first year the roots of the plants have not yet attained sufficient size to accommodate the insects at the time the latter are, with the exception, perhaps, of a few belated individuals, abroad and depositing their eggs; and thus the plants are almost, if not, indeed, entirely, exempt from attack the first year. Hence it is not until the summer of the second year that the plants are destroyed. This has led European entomologists to believe that, like many others of the Scolytidæ, the insect does not attack the plant until the latter has become weakened by age or is diseased. But in this country, at least, this can not be true, for the reasons just given. It is not improbable, however, that, as between two plants with roots of the requisite size, an unhealthy one would be preferred by the beetles rather than one in a thoroughly vigorous condition. But as yet there have been no observations tending to verify this hypothesis. A diseased clover root, or one that has begun to decline from effects of age, is first affected at the heart; and, as will be observed from figure 4, this is the part first attacked by the root-borer.

## EFFECT UPON THE PLANT.

While an infested clover plant sooner or later succumbs to an attack by this insect, life may be lengthened or shortened by meteorological conditions. Thus, if the spring or early summer is very dry, the plants begin to die in patches late in June, as soon as the hay crop is removed; but if there is much rain during this period, the weakened plants may continue to live until winter, dying out before spring. In either case the farmer is likely to be misled and to attribute the loss to the weather. The summer of 1905 was not a dry one. Copious rains fell with sufficient frequency to enable all but the most seriously affected plants to survive. A prominent seedsman of Indiana, who was much among clover fields, thus described the situation in October:

In driving around this year and examining clover fields, we have found that several fields which apparently should have produced an immense amount of seed, or at least, say, 3 or 4 bushels to the acre, * * * did not shake out anything. We pulled up some plants and discovered that the plant broke off at the crown; or if any of the root did come with it, it was small and decayed. On close investigation we discovered a little white worm which seemed to be in abundance and working amongst the roots. We noticed this in a number of fields and have been wondering what it was. We have also had samples of clover plants from other sections of Indiana showing these conditions, and almost invariably the yield of such fields was less than a bushel per acre, and in many instances hulling was abandoned and the huller taken out of the field.

### NATURAL ENEMIES.

While Doctor Riley found the larva of one of the common soldier beetles, probably *Telephorus bilineatus* Say, attacking the larvæ of the borer, and although it probably has other enemies, both among insects and birds, these have so far proven of little economic importance.

### PREVENTIVE MEASURES.

The only preventive measure yet tried that gives any promise of success is summer fallowing as soon as the hay crop is removed.

At this time the young are in an immature state and, if deprived of food, must perish. They can not migrate from one clover root to another, and, if the meadow is now broken up, throwing the roots up to the hot sun and winds, these wither and dry, thus no longer supplying the necessary sustenance, at this time so imperative to the life of the larvæ, and they perish. Thus an invasion of a new field from an old one may be prevented. But if the fallowing be delayed, even for a few weeks, the larvæ will then have for the most part passed into the pupal stage, during which no food is required, and plowing can have little or no effect upon them. This measure, together with the practice of allowing clover fields to stand only two years, would soon reduce the pest to subjugation in any community. No trouble from its work seems to occur in pastures. Once brought under control, it would seem that a system of rotation that involves mowing for hay and seed the first year, and pasturing and then breaking up the ground the following year, if generally followed in a community, would suffice to keep the pest in subjection. Extermination is not possible.

Approved:

James Wilson,
*Secretary of Agriculture.*

Washington, D. C., *January 12, 1910.*

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L. O. HOWARD, Entomologist and Chief of Bureau.

# CONTROL OF THE BROWN-ROT AND PLUM CURCULIO ON PEACHES.

BY

W. M. Scott, *of the Bureau of Plant Industry,*

AND

A. L. Quaintance, *of the Bureau of Entomology.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# CONTROL OF THE BROWN-ROT AND PLUM CURCULIO ON PEACHES.

By

W. M. SCOTT, *of the Bureau of Plant Industry*,

and

A. L. QUAINTANCE, *of the Bureau of Entomology.*

The two most important troubles of the fruit of the peach and other stone fruits are the so-called "brown-rot" (*Sclerotinia fructigenia* (P.) Schröt.) and the plum curculio (*Conotrachelus nenuphar* Herbst). The brown-rot is a fungous disease of the flowers, twigs, and fruit, but is especially destructive to the latter as it approaches maturity. Under weather conditions favorable to the fungus from one-half to three-fourths of the crop, or even the entire crop, may be destroyed within a few days. The marketed fruit, moreover, rarely reaches its destination in good condition and is often a disappointment to the grower as well as to the consumer. This destructive disease is well known to peach growers, especially in the Southern States, and requires but little in the way of description. Although young green fruit may become infected, it is the ripening fruit which suffers most. The disease first appears as a small brown spot, which rapidly enlarges, involving in a few days the entire fruit. On the surface of the diseased spots minute tufts of spore-bearing threads appear, giving to the fruit a grayish, moldy appearance.

The plum curculio, in the course of its feeding and egg laying, punctures the fruit, and is often so abundant that not a single fruit escapes injury. The punctures form a nidus for brown-rot spores, greatly favoring infection. Larvæ of the curculio, hatching from the eggs placed beneath the skin of the peach, make their way to the pit, and by their injury cause much of the young fruit to drop. Fruit infested later in the season may ripen prematurely and fall or be badly misshapen. Worminess of peaches in the East is entirely due to the plum curculio, and the injuries of this insect cause, in the aggregate, a loss each year to fruit growers of many thousands of dollars. As

 

the curculio, by its punctures, opens the way for brown-rot infection of peaches, plums, etc., its control becomes doubly important.

While the curculio is not of itself the cause of brown-rot, its work very greatly favors the disease. Furthermore, it is practically certain that the curculio distributes the spores of the fungus, and in the course of its feeding and egg laying actually infects the fruit with the fungus.

As is well known, the foliage of the peach and other stone fruits is especially sensitive to sprays, such as Paris green and Bordeaux mixture. This has largely prevented the use of Bordeaux mixture and other copper compounds for the control of peach diseases. While it has been known for several years that arsenate of lead could be used in the treatment for curculio, some injury has resulted, and on account of the well-known sensitiveness of peach foliage entomologists have been cautious about recommending it. The combination treatment for fungous diseases and insect enemies so successful in the treatment of the apple, grape, etc., has, therefore, not been possible on the peach.

The development of the self-boiled lime-sulphur mixture, however, as a fungicide has made possible the control of the brown-rot and some other peach diseases. The experiments made by the Bureau of Plant Industry, with the self-boiled lime-sulphur mixture on the peach, covering three years—from 1907 to 1909—have shown conclusively that when properly made it is perfectly harmless to the foliage, fruit, and tender growth of the peach, and that it will satisfactorily control brown-rot, peach scab, and other fungous diseases.

In experiments conducted during the past season it was found that the arsenate of lead could be combined with the self-boiled lime-sulphur mixture for spraying peaches, and that this insecticide was apparently less injurious in the combination than when used alone, and that the combination was entirely successful in controlling the scab, brown-rot, and curculio. The addition of arsenate of lead, as shown by these and other experiments, has been practically without injurious effects where not more than two applications have been made. Three applications, however, of an arsenate-of-lead spray are likely to cause shot-holing of the leaves and an excessive reddening of the fruit, and under certain weather conditions such symptoms may appear as the result of only two applications of the poison, though ordinarily not to an injurious extent. The great benefits to be derived from spraying, it is believed, will much more than offset any possible slight injury.

## SOME RESULTS OF SPRAYING.[a]

In experiments conducted in the Hale orchard, at Fort Valley, Ga., during 1909, by the Department of Agriculture, the practicability of the control of peach scab, brown-rot, and the curculio was

[a] For a detailed account of these experiments, see Bulletin 174 of the Bureau of Plant Industry, U. S. Department of Agriculture.

thoroughly demonstrated. Thus a block of 1,100 Elberta trees was sprayed, first, with arsenate of lead at the rate of 2 pounds to 50 gallons of water at the time the calyces, or shucks, were shedding; second, with 2 pounds of arsenate of lead in self-boiled lime-sulphur mixture (8–8–50) three weeks later; third, with self-boiled lime-sulphur mixture alone a month later; and, fourth, with self-boiled lime-sulphur mixture a month before the ripening period of the fruit. At picking time 95.5 per cent of the fruit from the sprayed block was free from brown-rot, 93.5 per cent free from scab, and 72.5 per cent free from the curculio. On the unsprayed block only 37 per cent of the fruit was free from brown-rot, 1 per cent free from scab, and 2½ per cent free from curculio injury. In packing the fruit for market it was found that the amount of merchantable fruit on the sprayed block was ten times as great as from the unsprayed block containing the same number of trees.

On a block of Waddell trees sprayed with the self-boiled lime-sulphur mixture alone, one month after the falling of the petals and again one month before the fruit ripened, the results were not quite so good, owing to curculio infestation; but the yield of merchantable fruit was, nevertheless, 100 per cent more than that on a similar block of unsprayed trees of the same variety.

From these results and those of previous experiments we may conclude that the peach grower now has at his command a reasonably safe and thoroughly effective remedy for the peach scab, brown-rot, and curculio. By carefully following the instructions given below he should be able effectively to prevent these troubles at a small cost.

## PREPARATION OF THE SPRAY MIXTURES.

The sprays to be employed are the self-boiled lime-sulphur mixture and arsenate of lead. The arsenical is added to the lime-sulphur mixture, permitting the treatment of both brown-rot and the plum curculio at one and the same time.

*Self-boiled lime-sulphur mixture.*—This mixture is composed of 8 pounds of fresh stone lime and 8 pounds of sulphur (either flowers or flour may be used) to 50 gallons of water. This appears to be about the correct strength, although in mild cases of scab and brown-rot a weaker mixture, containing 6 pounds of each ingredient to 50 gallons of water, may be used with satisfactory results. The mixture can best be prepared in rather large quantities—say, enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added after first running it through a sieve to break up the

lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

The stage at which cold water should be poured on to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot fifteen or twenty minutes after the slaking is completed, the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through the strainer.

*Arsenate of lead.*—Arsenate of lead comes on the market in a thick, putty-like paste, and must be worked free in water before addition to the lime-sulphur mixture. There are several brands upon the market and the grower should be careful to purchase from reliable firms. The addition of arsenate of lead to the self-boiled lime-sulphur mixture will bring about a decided change in color, but without injuriously affecting the value of the spray. Arsenate of lead is used at the rate of 2 pounds to each 50 gallons of water or lime-sulphur mixture.

The amount of poison required for each spray tank of mixture may be weighed out into a bucket, thinned with water, and poured through a strainer into the spray tank. In extensive operations, however, it is much more convenient to prepare a stock mixture in advance. Place 100 pounds of the material in a barrel with a bucket of water and work it into a thin paste with a spade or a large paddle, then dilute with water to make exactly 25 gallons. When thoroughly stirred, each gallon will contain 4 pounds of arsenate of lead, and the amount of poison for each spray tank of mixture may be measured, thus avoiding the trouble of weighing small lots.

## SCHEDULE OF APPLICATIONS.

For the Elberta, Bell, Reeves, and other varieties of peaches of about the same ripening season, the following is advised:

*First application.*—About the time the calyces, or shucks, are shedding from the young fruit, spray with arsenate of lead at the rate of

2 pounds to 50 gallons of self-boiled lime-sulphur mixture. Since this application is rather early for scab, and since serious outbreaks of brown-rot do not usually occur at this time, the self-boiled mixture may be omitted in many cases with reasonable safety. But during warm, rainy springs, especially in the South, the lime-sulphur mixture will doubtless be necessary in this application. In case the self-boiled lime-sulphur mixture is not used there should be added to each 50 gallons of water the milk of lime made from slaking 2 or 3 pounds of good stone lime, in order to counteract any caustic action of the arsenate of lead.

*Second application.*—Two or three weeks later, or about one month after the falling of the petals, spray with the 8–8–50 self-boiled lime-sulphur mixture and 2 pounds of arsenate of lead.

*Third application.*—About one month before the fruit ripens spray with the 8–8–50 self-boiled lime-sulphur mixture, omitting the poison.

For earlier maturing varieties of peaches, such as Waddell, Carman, and Hiley, the first two treatments outlined above will usually be sufficient, but in very wet seasons badly rotting varieties would probably require three treatments. Late varieties, such as Smock and Salway, having a longer season, would not be thoroughly protected by three applications, but on account of the expense there is hesitation in recommending a fourth spraying. In view of the results obtained on midseason varieties, it seems likely that three treatments will ordinarily be sufficient for the late varieties.

## APPLICATION OF THE SPRAY MIXTURE.

During the operation of spraying, the mixture should be kept well agitated. Owing to the tendency of the self-boiled lime-sulphur mixture and the arsenate of lead to settle readily, this point can not be too strongly emphasized. If the spraying outfit is not equipped with a good agitator, the spray will not be evenly distributed, with the result that some of the trees will be oversprayed while others will receive an insufficient application. The early applications of spray should be made rather heavy and very thoroughly to insure the destruction of the curculio and protection against scab. The last spraying, a month before ripening time of the fruit, should be made with fine nozzles, the object being to give the fruit a uniform coating of a mistlike spray. Heavy drenching of the trees at this time should be avoided, to guard as much as possible against the staining of the fruit at picking time.

Approved:

James Wilson,

*Secretary of Agriculture.*

Washington, D. C., *February 25, 1910.*



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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—CIRCULAR No. 121.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE OYSTER-SHELL SCALE AND THE SCURFY SCALE.

BY

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AND

E. R. SASSCER, *Scientific Assistant.*

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CIRCULAR No. 121. Issued April 30, 1910.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE OYSTER-SHELL SCALE AND THE SCURFY SCALE.

(*Lepidosaphes ulmi* L. and *Chionaspis furfura* Fitch.)

By

A. L. QUAINTANCE, *In Charge of Deciduous Fruit Insect Investigations,*

and

E. R. SASSCER, *Scientific Assistant.*

## INTRODUCTION.

The oyster-shell scale (*Lepidosaphes ulmi* L.) and the scurfy scale (*Chionaspis furfura* Fitch) are, with the exception of the San Jose or Chinese scale (*Aspidiotus perniciosus* Comst.), more frequently the subject of inquiry by orchardists than all other species of scale insects combined. These two scale pests are now very generally distributed throughout the country, and from their relatively conspicuous appearance are often detected by observant fruit growers who frequently believe them to be the more serious San Jose scale. The oyster-shell and scurfy scales, while not dangerous in the sense of generally causing the death of infested trees, are, however, of considerable economic importance. The complete killing of individual branches of apple trees by either species is a matter of frequent observation, and trees so badly infested are frequently greatly stunted and retarded in their growth, resulting perhaps in extreme cases in the death of the trees. Of the two species considered, the oyster-shell scale has been and is at the present time the more important. Its injuries to certain shade trees, especially poplar and maple, have been the cause of much complaint during recent years. Such shade trees are ordinarily not sprayed for scale insects, and the increase of these pests from year to year is thus checked only by their natural enemies. The writers have frequently seen maple and poplar trees literally incrusted from top to bottom with the oyster-shell scale, many of the limbs killed, and in rarer instances the trees quite dead—without doubt owing to the attack of this scale insect.

## THE OYSTER-SHELL SCALE.

(*Lepidosaphes ulmi* L.)

### ORIGIN AND DISTRIBUTION.

The origin of the oyster-shell scale is a matter of some uncertainty. It has a world-wide distribution, and was introduced into the New England colonies at an early date. The first American account of this pest was written by Enoch Perley in 1794, in which he stated that it was doing considerable damage to the apple in Cumberland County, Maine. In the early sixties it had reached the Mississippi River, and at the present writing (April, 1910) occurs in every State of the Union with the possible exception of South Dakota, Oklahoma, and Texas. Its occurrence in these States is practically certain, but there appear to be no records in literature to this effect, and it has not been received from these States by the Bureau of Entomology. The insect is very troublesome in the Northern States and is especially common in the New England States and those bordering the Great Lakes.

### DESCRIPTION AND LIFE HISTORY.

This insect has received the common name "oyster-shell scale," owing to the resemblance of its scale or covering to a long, narrow oyster shell, as may be seen by reference to figure 1. The adult female scales are about one-eighth of an inch in length, usually brown to dark brown in color, though occasionally they have a grayish appearance which is due to bleaching over winter. If present in large numbers, for want of room they assume various more or less curved shapes. The scale of the male in shape and color resembles that of the female, but is smaller and possesses at the posterior extremity a small hinge or flap which permits the exit of the adult male.

If during winter or early spring one of the female scales be removed, numerous small, oval, white eggs varying in number from 40 to 100 will be revealed, and at the anterior portion can be seen the dead and shriveled body of the female.

In Canada and the Northern States there is thought to be but one full brood annually, whereas in the Middle and Southern States the species is double brooded.

The following records from literature and from the Bureau of Entomology will indicate the time in the spring of hatching of the eggs of this insect, in various localities. This time will, of course, vary with the season, but, in general, as long ago stated by Doctor Mygatt, in Illinois, will for any locality be shortly after the time of the falling of the blossoms of the apple.

*Ontario:* Eggs hatch about first week of June (Jarvis).

*New York:* Eggs hatch latter part of May to early June (Felt).

*New Hampshire:* Eggs hatch in late May to early June (Sanderson).

*Vermont:* Eggs hatch in late June (Stewart).

*Maine:* Eggs hatch about middle of June or later, depending upon the season (Hitchings).

*Michigan:* In specimens received June 18, 1909, from Stittsville, Mich., nearly all eggs had hatched (Sasscer).

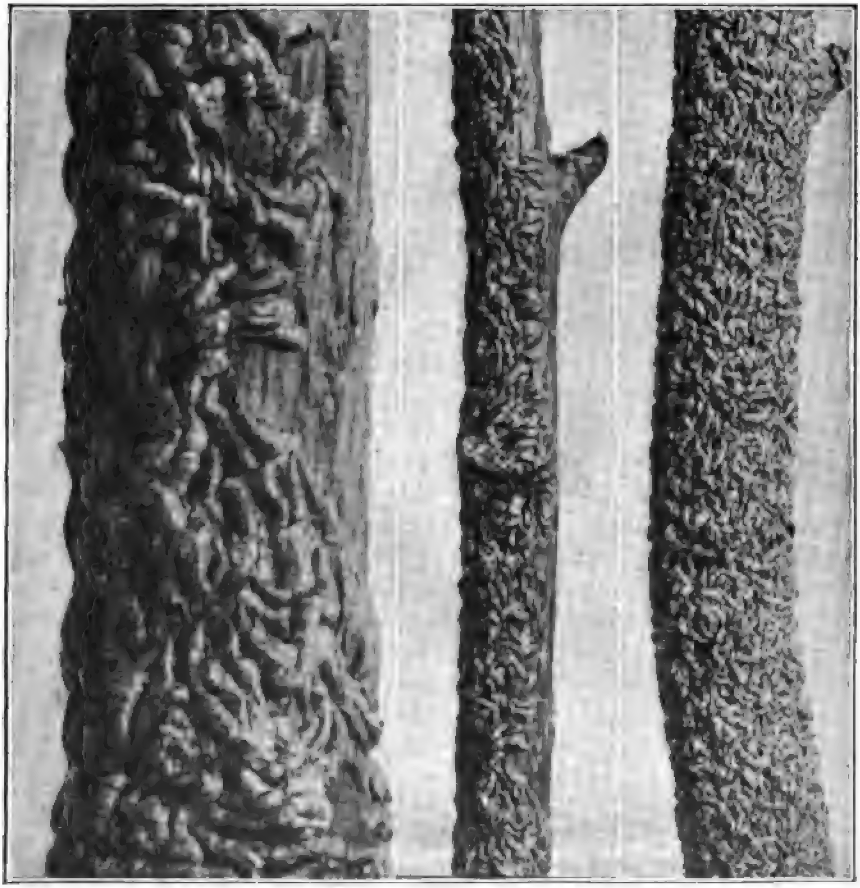

FIG. 1.—The oyster-shell scale (*Lepidosaphes ulmi*). All enlarged. (Original.)

*Minnesota:* In specimens received May 24, 1909, from Lamoille, Minn., eggs were hatching in numbers when received (Sasscer).

*Indiana:* In specimens received from Elwood, May 14, 1909, eggs were hatching in numbers when received (Sasscer).

*Ohio:* Eggs hatch in late May to early June (Gossard).

Second-brood eggs were found under many scales August 22, and a few young crawling at Cleveland (Quaintance).

*West Virginia:* In specimens received April 30, 1908, from Parkersburg, W. Va., young were crawling in numbers (Sasscer).

*Missouri* (Wright County): Eggs hatch early in May. Insect double brooded according to a Mr. Wright (Riley).

Olden, Mo., eggs hatched March 29, 1907; apple trees bloomed March 24 (Girault).

Ozark region, Missouri, eggs hatch about April 25 to middle of May (Taylor).

*Illinois* (Cook County): Eggs hatch about June 6, females reach full growth by August 1, and oviposit August 12–28 (Riley).

*District of Columbia:* Eggs hatch May 5–14 (Quaintance).

July 4, eggs already deposited by most females and young crawling (Quaintance).

*Maryland:* Eggs hatch early in May (Symons).

Eggs of first brood hatch in May; eggs of second brood hatch last week of July to first week of August (Johnson).

College Park, many recently settled scales in evidence May 21 (S. W. Foster).

*Delaware:* Eggs usually hatch in early May (Houghton).

*New Jersey:* Eggs hatch during early June (Smith).

*Tennessee:* In eastern Tennessee eggs hatch during first two weeks of April (Chambliss).

Eggs begin to hatch in April and those of the second brood along in July and August (Bentley).

This information as to the period of hatching of eggs in various parts of the country is of importance as bearing on the time to spray for the destruction of the young larvæ.

The female molts twice in the course of her growth, and in the adult condition is entirely without legs or eyes, being nothing more than a reproductive sack with her sucking mouth parts, through which the food is taken, inserted in the tissues of the plant. The adult male differs radically from the female in that it is provided with antennæ and one pair of wings, the second pair being present in the form of club-shaped organs known as balancers or halteres. During the process of metamorphosis the mouth parts entirely disappear, and a second pair of rudimentary eyes assumes their place. Being without any means of taking in food the male is naturally very short lived, its only mission appearing to be the fertilization of the female.

## MEANS OF DISTRIBUTION.

Transportation by nursery stock, scions, or by grafting or budding material is perhaps the only way this insect is carried from one section of the country to another, and this in a large measure accounts for its wide distribution. Locally it can be transferred from plant to plant only while in the young or crawling stage. The young are often seen crawling on other insects, such as beetles, or upon the feet of birds, and may in this way be carried some distance. Man and domestic animals may also assist in their dissemination, and it is possible that the winds blow them from plant to plant.

## FOOD PLANTS.

The oyster-shell scale has a wide range of food plants, but is commonly found on apple, maple, horse-chestnut, poplar, willow, and

lilac. The following is a list of the plants on which it is known to occur:

Alder (*Alnus rugosa* Spreng.).
Almond (*Prunus* sp.), China.
American aspen (*Populus tremuloides* Michx.).
American bladdernut (*Staphylea trifolia* Linn.).
*Amorpha* sp., exotic.
Apple (*Pyrus malus* Linn.).
Apple, crab (*Pyrus* sp.).
Apricot (*Prunus armeniaca* Linn.).
Arrow-wood (*Viburnum* spp.).
Ash (*Fraxinus americana* Linn.), (*F. excelsior* Linn.), (*Fraxinus* spp.).
Balm of Gilead (*Populus balsamifera* Linn.).
Basswood (*Tilia americana* Linn.), (*T. angustifolia*, from Germany).
Beech (*Fagus atropunicea* Sudw.).
Bilberry (*Vaccinium myrtillus* Linn.).
Birch, white (*Betula populifolia* Ait.).
Birch, river (*Betula nigra* Linn.).
Bittersweet (*Celastrus* sp.).
Blackthorn (*Prunus spinosa* Linn.).
Box (*Buxus sempervirens* Linn.).
Boxelder (*Acer negundo* Linn.).
Broom (*Cytisus scoparius* Link.), Gurnsey. (*C. nubigenus* Link.), from Gurnsey (?).
Buckeye (*Æsculus glabra* Wild.).
Buckthorn (*Rhamnus cathartica* Linn.).
Butternut (*Juglans cinerea* Linn.).
*Calluna* sp., Sweden.
*Camellia* sp.
Camphor tree (*Camphora officinalis* Steud.).
*Cassia* sp., in greenhouse.
Cherry (*Prunus* sp.).
Chestnut (*Castanea americana* Raf.).
*Clematis paniculata* Thunb.
Cocoa palm from Barbados.
*Cotoneaster* sp.
Cranberry (*Vaccinium* sp.).
Currant, black (*Ribes nigrum* Linn.).
Currant, red (*Ribes rubrum* Linn.).
Dogwood (*Cornus alba* Linn.), (*C. alba* var. *sibirica* Lodd.), (?*C. alterna* Marsh), (*C. californica* C. A. Mey), (*C. sanguinea* Linn.).
Elm, English (*Ulmus campestris* Smith).
Elm, purple-leaved (*Ulmus scabra*, var. *purpurea* Koch).
? *Euphorbia palustris* Linn., Germany.
False bittersweet (*Celastrus scandens* Linn.).
Fig (*Ficus carica* Linn.).
Filbert (*Corylus* sp.).
Ginseng (*Panax quinquefolium* Linn.).
Gooseberry (*Ribes cynosbati* Linn.).
Goatsbeard (*Aruncus sylvester* Kost.).
Grape (*Vitis vinifera* Linn.).
Hackberry (*Celtis occidentalis* Linn.).
Hawthorn (*Cratægus crus-galli* Linn.), (*C. oxyacantha* Linn.).
*Helianthemum chamæcistus* Mill., England.
Heath (*Erica* sp.), England and Sweden.
Heather (*Calluna* sp.).
Holly (*Ilex crenata* Thunb.).
Honeysuckle (*Lonicera* sp.).
Hop tree (*Ptelea trifoliata* Linn.).
Horse-chestnut (*Æsculus hippocastanum* Linn.).
*Horena dulcis* Thunb.
June-berry (*Amelanchier* spp.).
Leather leaf (*Chamædaphne calyculata* Moench).
Lilac (*Syringa persica* Linn.), (*S. vulgaris* Linn.).
Lime (*Citrus* sp.).
Linden. (*See* Basswood.)
Locust, cultivated (*Robinia pseudacacia* Linn.).
Locust, water (*Gleditsia aquatica* Marsh).
Maple, striped (*Acer pennsylvanicum* Linn.).
Maple, sugar (*Acer saccharinum* Linn.).
Maple, mountain (*Acer spicatum* Lam.).
*Mespilus cuneata* Miq., Japan.
Mosse-wood (*Dirca palustris* Linn.).
Mountain ash (*Sorbus americana* Marsh).
Mountain ash, European (*Sorbus aucuparia* Linn.).
Myrtle (*Myrtus* sp.), Egypt.
Nectarine (*Prunus* sp.).
New Jersey tea (*Ceanothus americanus* Linn.).
Oak (*Quercus pedunculata* Ehrh.), (*Quercus* spp.), Germany.
Orchid.
*Pachysandra terminalis* Sieb. & Zucc.
Peach (*Prunus persica* Sieb. & Zucc.).
Pear (*Pyrus communis* Linn.).
Pear, Sickle.

Peony (*Pæonia* sp.).
Peppergrass (*Lepidium suffruticosum* Linn., Cav.), France.
*Planera keakei* C. Koch.
Plum (*Prunus domestica* Linn.).
Poplar, Lombardy (*Populus nigra* var. *italica* Du Roi).
Poplar, white (*Populus alba* Linn.).
Quince (*Cydonia vulgaris* Pers.).
Raspberry (*Rubus idæus* Linn.).
Rose (*Rosa rugosa* Thunb.).
Sassafras (*Sassafras sassafras* Karst.).
Silverberry (*Elæagnus argentea* Pursh.).
*Spiræa* spp.
Spruce (*Abies firma* Sieb. & Zucc.).
Sycamore (*Platanus* sp.).
Tallow tree (*Sapium sebiferum* Roxb.).
Tamarisk (*Tamarix africana* Poir.).
Tree of Heaven (*Ailanthus glandulosa* Desf.).
Tulip-tree (*Liriodendron tulipifera* Linn.).
Umbrella tree (*Magnolia tripetala* Linn.).
*Viburnum* sp.
Virginia creeper (*Ampelopsis quinquefolia* Michx.).
Willow, goat (*Salix caprea* Linn.).
Willow, Napoleon (*Salix babylonica* Linn.).
Willow, osier (*Salix viminalis* Linn.).
Willow, (*Salix ægyptiaca* Forsk.). } Algeria.
Willow, (*Salix pedicellata* Desf.). }
Walnut, English (*Juglans regia* Linn.).
Walnut (*Juglans* sp.).
Yucca (*Yucca* sp.).

### PARASITIC AND PREDACEOUS ENEMIES.

Minute parasitic Hymenoptera are often efficient enemies of this scale, and in some localities they apparently hold the insect in check. If these little friends are present, small round holes can be seen on the dorsal part of the scale showing where the adult escaped. Those more commonly found are *Aphelinus mytilaspidis* Le B., *A. abnormis* How., *A. fuscipennis* How., *A. diaspidis* How., *Aspidiotiphagus citrinus* How., *Anaphes gracilis* How., and *Cheiloneurus diaspidinarum* How.

The larvæ of coccinellids, or ladybeetles, are sometimes found feeding on these insects, and certain species of mites assist in their destruction. Birds are also credited with doing service, the most efficient being the titmice and tree creepers.

## THE SCURFY SCALE.

(*Chionaspis furfura* Fitch.)

The scurfy scale, while infesting a considerable number of plants, is a less general feeder than is the preceding species. It occurs principally upon rosaceous plants, such as the apple, peach, pear, plum, cherry, etc., and also on currant and gooseberry among cultivated plants, but seldom becomes so abundant as to cause particular injury or to require specific treatment. The insect may be recognized from the accompanying illustration (fig. 2), much enlarged. The scale of the female is dirty gray in color, irregularly pear-shaped, as shown in the picture. The male scales are much smaller, elongate, snowy white, with three distinct keels extending longitudinally along the back. Unlike the former species, the scurfy scale is a native North American insect, and appears to be less adaptable to

the various conditions throughout the country, and has thus a more restricted distribution.

## LIFE HISTORY AND HABITS.

The scurfy scale, like the oyster-shell scale, winters in the egg condition under the scales. The number which may be deposited

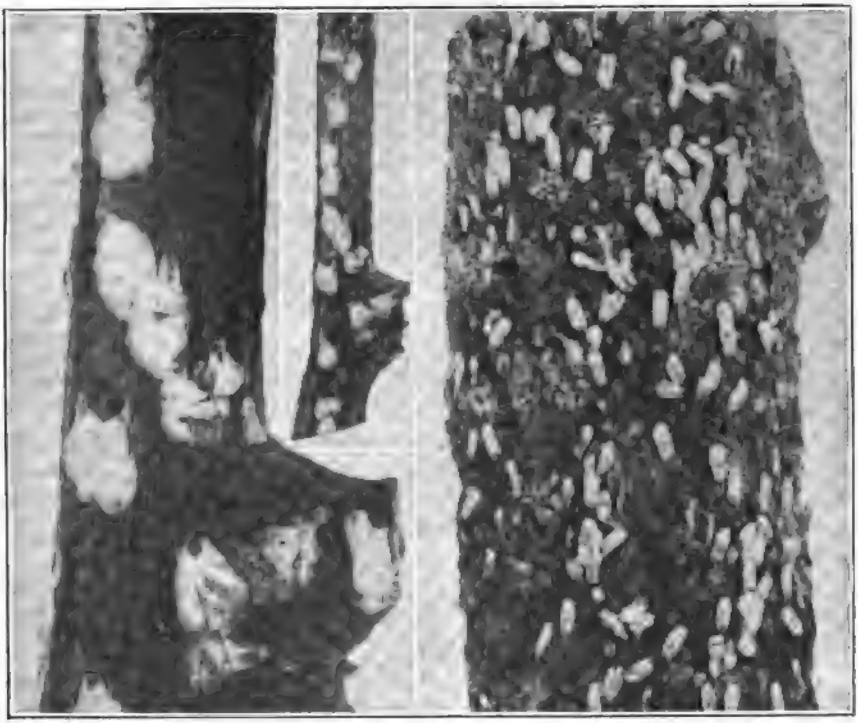

**Fig. 2.—The scurfy scale (*Chionaspis furfura*). Male at right, female at left. All enlarged. (Original.)**

by a given female, as may be easily verified by examination, varies considerably. The following records show the number of eggs from each of twenty individuals:

*Number of eggs deposited by the scurfy scale. (Material collected on apple sprouts from base of apple stump March 31, 1905, at Arlington Farm, Virginia.)*

| Scale No. | Eggs. | Scale No. | Eggs. | Scale No. | Eggs. | Scale No. | Eggs. |
|---|---|---|---|---|---|---|---|
| 1 | 61 | 6 | 74 | 11 | 54 | 16 | 82 |
| 2 | 18 | 7 | 78 | 12 | 61 | 17 | 23 |
| 3 | 78 | 8 | 70 | 13 | 48 | 18 | 83 |
| 4 | 98 | 9 | 19 | 14 | 68 | 19 | 21 |
| 5 | 53 | 10 | 41 | 15 | 78 | 20 | 33 |

Average number of eggs per scale, 57.5.

The following records from literature and from the Bureau of Entomology will indicate the times of hatching of the eggs of this insect in the spring for several localities:

*Ontario:* Eggs hatch about June 1 (Jarvis).

*Connecticut:* Eggs hatch usually between May 20 and June 1 (Britton).

*New York:* Eggs hatch at about same time as those of oyster-shell scale.

*Ohio:* Eggs hatch, and young are crawling, during latter part of May or in early June (Houser).

*Illinois:* Eggs hatch from June 5 to 12 (Walsh).

*Missouri:* Eggs hatch soon after the formation of the young apples, the date depending upon locality and upon forwardness of the spring (Taylor).

*District of Columbia:* Eggs hatch from May 15 to June 1 (Howard).

*Delaware:* Eggs hatch about same time as those of oyster-shell scale, which is usually early in May (Houghton).

*Tennessee:* Eggs hatch in April, and there are two broods annually (Bentley).

*Georgia:* In 1906 eggs hatched March 11 to 22. Eggs for second brood hatched beginning about June 2.

In the more northern States there is but one brood each year, but in the South, as in Tennessee and in Georgia, there are evidently two full broods, and in the latter State there is a strong probability of a third. Thus, at Myrtle, Ga., in 1906, the eggs were hatching March 11, and hatching had probably ceased by March 22. Males of the new brood appeared May 15, and eggs had been deposited by the female May 28, the hatching beginning June 2.

## DISTRIBUTION.

The following records of distribution have been compiled from various publications and from data collected by the Bureau of Entomology:

California, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska. New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Virginia, Washington, West Virginia, and Wisconsin. In Canada it is recorded from New Brunswick, Nova Scotia, Ontario, and Prince Edward Island.

## FOOD PLANTS.

The following list includes all plants upon which this species has been found, so far as it has been possible to determine from records in literature and from those in the Bureau of Entomology:

Apple (*Pyrus malus* Linn.).
Apple, Chinese flowering (*Pyrus spectabilis* Ait.).
Apple, crab (*Pyrus* sp.).
Ash, European mountain (*Sorbus aucuparia* Linn.).
Ash, mountain (*Sorbus americana* Ait.).
Ash, prickly (*Xanthoxylon americanum* Mill.).
Ash, white (*Fraxinus americana* Linn.).
Aspen, largetooth (*Populus grandidentata* Michx.).
Buckthorn (*Rhamnus cathartica* Linn.).
Cherry, choke (*Prunus virginiana* Linn.).
Cherry, wild black (*Prunus serotina* Ehrh.).
Cherry, wild red (*Prunus pennsylvanica* Linn.).
Chokeberry (*Pyrus floribunda* Lindl.).
Chokeberry, black (*Sorbus melanocarpa* C. Koch).
Chokeberry, red (*Sorbus arbutifolia* C. Koch).
"Cherry currant."
Currant, red flowered (*Ribes sanguineum* Pursh.), England.
Elm (*Ulmus* sp.).
Gooseberry (*Ribes* sp.).
Hawthorn (*Cratægus oxyacantha* Linn.).
Hickory, big bud (*Hicoria alba* Britt.).
Horse chestnut (*Æsculus hippocastanum* Linn.).
Peach (*Prunus persica* Sieb. & Zucc.).
Pear (*Pyrus communis* Linn.), (*P. heterophylla* Dur.).
Plum (*Prunus pissardii* Hort.).
Plum, common garden (*Prunus domestica* Linn.).
Quince (*Cydonia vulgaris* Pers.).
Quince, Japanese (*Cydonia japonica* Pers.).
Raspberry, black cap (*Rubus occidentalis* Pers.).
Red-twigged dogwood (doubtful record).
Shad-bush (*Amelanchier canadensis* Medic.).
Sweet gum (*Liquidambar* sp.).
Sweet pepper bush (*Clethra alnifolia* Linn.).
Walnut, black (*Juglans nigra* Linn.).
Willow, white (*Salix alba* Linn.).

The scurfy scale is especially common on apple and pear, less usually so on cherry and peach, on which latter host in the South, in certain cases which have come under the writers' observations, it proved very destructive, greatly stunting the trees, although none had actually been killed.

## PARASITIC AND PREDACEOUS ENEMIES.

This species is apparently not so subject to attack of parasitic and predaceous insects as the preceding, or else attention has not been directed to this phase of the insect's economy to an equal extent. The following predaceous species are recorded as feeding upon the scurfy scale: *Tyroglyphus malus* (Shimer), *Chilocorus bivulnerus* Muls., and *Hyperaspidis* sp.

Among the parasitic Hymenoptera, *Ablerus clisiocampæ* (Ashm.) has been reared from this species, as well as *Physcus varicornis* How., and a species of the genus *Prospaltella*.

## METHODS OF CONTROL FOR BOTH SPECIES.

Preparatory to spraying orchard, shade, and ornamental trees and plants for scale insects, they should be carefully gone over and any dead and weakened parts pruned out. The presence of such dead and dying wood is a distinct detriment, and its removal will greatly simplify the work of spraying.

TREATMENT OF ORCHARDS.

In orchards well sprayed during the dormant period for the San Jose scale each year, the oyster-shell and scurfy scales will rarely prove troublesome. While these insects, by reason of wintering in the egg stage under the protecting female scales, are less susceptible to washes effective against the San Jose scale, yet the treatments will in most cases keep them reduced below injurious numbers.

In orchards where spraying for the San Jose scale is unnecessary and where the oyster-shell or scurfy scales are troublesome, specific treatments become necessary. There is considerable difference of opinion among entomologists as to the effectiveness of sprays applied during the dormant season to effect the destruction of the eggs, but there is greater uniformity as to the effectiveness of spraying shortly after the young have hatched and before there has been time for the formation of a thick protecting scale.

Thus Messrs. Parrott, Beach, and Sirrine,[a] referring to the scurfy scale, state:

> During the work of the past two years opportunities have been given to note the effects of the sulphur washes upon this species. In several instances where the infestation was moderate, such treatment has usually checked the further development of the scales. When the incrustation was heavy, the results attending the application of the washes have shown some variation in the amount of reduction of the scales, but there has usually been a very appreciable destruction of the insects.

Writing of the oyster-shell scale, Mr. William Stuart says:[b]

> Early spring applications do not appear to be a practicable method of eradicating the oyster-shell scale. Summer treatment of infested trees, soon after the young have hatched, with dilute kerosene emulsion, whale-oil soap, or tobacco infusions affords a much more effective means of combating this pest.

Experiments were made by Mr. Stuart in the use of the cooked lime-sulphur wash in 1904, and the kerosene-limoid mixture in 1905. In 1906 tests were made of the cooked lime-sulphur sprays. All applications were made during the dormant period of the trees.

The Rev. Chas. J. S. Bethune states:[c]

> Owing to the large number of applicants who were desirous of obtaining information on the best methods of combating the oyster-shell bark louse, it was decided to carry on a number of experiments here, to test the efficiency of the various insecticides commonly used against scale insects.
>
> Of all the spray mixtures tried, the well-known lime, salt, and sulphur wash gave the best results.
>
> The lime, sulphur, and caustic soda, and the lime, sulphur, and sal soda were also tried, but without quite such good results. The lime, sulphur, and caustic soda proved to be a little superior to the lime-sulphur and sal soda, owing to its apparent power of better penetration.

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[a] Bul. 262, N. Y. Agr. Exp. Sta. (Geneva), 1905.
[b] 19th Ann. Rep., Vermont Agr. Exp. Sta., p. 294, 1907.
[c] 32d Ann. Rep. Ont. Agr. Coll. and Exp. Farm, p. 48, 1906.

*Soaps.*—Various soaps were also tried, and of these the whale-oil-soap emulsion gave the best results, many of the scales being killed. The whale-oil soap gave good results also, but not equal to the emulsion.

*Kerosene emulsion.*—Kerosene emulsion was also tried, and this proved of more value than the whale-oil-soap emulsion, but not so effective as the lime, salt, and sulphur wash.

*Lime.*—Quick slaked lime, 1½ pounds to 1 gallon of water, proved very effective applied as a winter wash, and equaled the results obtained by the lime, salt, and sulphur.

*Kerosene lime.*—This was also tried, but did not prove superior to the kerosene emulsion, and therefore is not to be preferred to it.

Prof. T. B. Symons,[a] as a result of tests of sprays upon the oyster-shell scale on shade trees in 1906, concludes:

That maple trees infested with the oyster-shell scale can be treated both in the fall and early spring with the lime-sulphur and salt wash with satisfactory results as regards controlling the pest, and without injury to the trees.

That where one application is made these tests showed the fall treatment to be preferable. It is the writer's belief, however, that when the wash is applied thoroughly in early spring equally good or even better results can be obtained.

The Duke of Bedford and Spencer U. Pickering[b] report results of detailed experiments with various washes in the destruction of the eggs of this insect, and found that a 3 per cent caustic soda wash gave 100 per cent efficiency in killing the eggs. A 2.5 per cent caustic soda wash with soap also gave excellent results, but difficulty was experienced in handling the wash on account of its becoming semisolid. Results of tests of other washes are presented, as caustic soda and potash, paraffin emulsion, emulsion soda washes, emulsions with lime, lime-sulphur soda washes, etc.

Concerning the scurfy scale, Mr. J. S. Houser[c] states:

That the lime-sulphur wash applied during the winter is effective, as are also contact sprays applied at hatching time.

The same author (l c.), in speaking of the oyster-shell scale, states:

The lime-sulphur wash is undoubtedly the control method to be used against this scale, but in the author's experience, it has proven somewhat of a disappointment. From observations made upon hundreds of trees and shrubs, sprayed with a mixture made by experienced men and applied thoroughly, it is apparent that only when conditions are the most favorable are the results following its use satisfactory. A slight dampness, such as a light fog at the time of application, a somewhat weakened spraying mixture, an extra case of infestation, where several scales are piled upon one another, a temperature below 32 degrees—any of these unfavorable conditions is sufficient to give poor results.

Prof. R. A. Cooley[d] presents results of extensive tests of sprays for the destruction of the oyster-shell scale: (1) As against the eggs dur-

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[a] Bul. 111, Md. Agr. Exp. Sta., 1906.

[b] 8th Rep. Woburn Exp. Fruit Farm, p. 33, 1908.

[c] Bul. 194, Ohio Agr. Exp. Sta., 1908.

[d] Journ. Econ. Ent., vol. 3, p. 57, 1910.

ing dormant period of trees; (2) early during hatching period of eggs, and (3) late during hatching period of eggs. The results were not entirely consistent, and further experiments are promised. The two following points, however, are emphasized:

(A) Eggs of the oyster-shell scale are unaffected by the application of lime-sulphur solutions made previous to the opening of the buds. On trees so sprayed the young were killed very soon after hatching. The intervention of rain storms before the hatching of the eggs may more or less affect the value of the treatment.

(B) It is indicated that emulsions of linseed oil and cottonseed oil may be useful for the treatment of this insect while in the egg stage and during the hatching period.

On the whole, therefore, it would appear preferable, where the destruction of these insects alone is to be considered, to spray as the young insects are hatching in the spring. The table of dates of hatching given under the remarks on life history for each species will indicate approximately when the young insects may be expected to appear, but this time may be accurately determined by frequent examinations of the infested trees. The very small, yellow insects will be seen in numbers crawling over the limbs and branches in their efforts to find a suitable place for settling.

The data on the dates of hatching of the two species, considered in connection with blooming dates of fruit trees, indicate that for any locality the young of both species will have hatched and settled, and may be effectively treated during the period of from one to three weeks following the blooming period of the apple; and from two to four weeks after the period of blooming of the peach. It will be preferable, however, positively to determine the time of crawling of the young for the particular locality and food plant, by actual observations.

In spraying for the young insects when the trees are in foliage, the presence of the leaves will render thorough work more difficult, and especial care will be necessary to reach all limbs and branches, treating every portion of the tree from top to bottom, as only those insects actually hit are destroyed. A weaker wash must also be employed than during the dormant season, as will be indicated later under the head of formulas, or else injury to the foliage and fruit may result.

## TREATMENT OF SHADE TREES.

The oyster-shell scale will often require treatment on maples, Lombardy and Carolina poplars, ash, and willow. As these trees will be rarely sprayed during the dormant period for other scale pests, it will be advisable to give the treatment just after the hatching of the young, as already explained. Effective spraying of shade trees, when these are of some size, will require painstaking work. In many cases it will be necessary for the man handling the nozzle to climb

into the trees to reach the higher limbs and branches and a long extension or bamboo rod is indispensable. The length of hose must be adapted to the height of the trees to be treated, and a coarse nozzle, such as the Bordeaux, will be preferable, as enabling the operator to throw the spray some distance to inaccessible branches. A high-pressure pump, from 150 to 200 pounds, is especially desirable, though the writers have seen good work accomplished with an ordinary barrel outfit.

Spraying during the dormant season, however, may be practiced, if the work may be more conveniently accomplished during this time, using one of the winter sprays later mentioned, as lime-sulphur wash, kerosene or crude petroleum emulsion (20 to 25 per cent strength), or some of the miscible oils.

### TREATMENT OF CURRANTS, GOOSEBERRIES, ORNAMENTAL SHRUBS, AND OTHER LOW-GROWING PLANTS.

After proper pruning, shrubs and bushes infested with these two scale pests should be thoroughly sprayed, preferably as the young are hatching in the spring, using the summer-strength kerosene or crude-petroleum emulsion or whale-oil soap wash. A knapsack or bucket pump will be suitable for treating a few plants in yards, and in view of the small amount of labor involved, a supplementary application is advisable in a week or ten days to destroy any belated larvæ which escaped the first application. Where infested yard plants are growing close to the wall of a building, this may be protected during the operation of spraying by a piece of tarpaulin or other heavy cloth, or even refuse paper.

### SPRAY FORMULAS.

*Kerosene emulsion (stock solution, 66 per cent oil).*—Kerosene emulsion is made after the following formula:

| | | |
|---|---|---|
| Kerosene (coal oil, lamp oil) | gallons.. | 2 |
| Whale-oil or laundry soap (or 1 quart soft soap) | pound.. | ½ |
| Water | gallon.. | 1 |

The soap should first be dissolved in boiling water; then remove vessel from the fire. Immediately add the kerosene, and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump, and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before using. In order to make a 10 per cent spray (the strength for trees in foliage) add to each 1 gallon of the stock solution about 5¾ gallons of water. For 20 and 25 per cent emulsions (for use on dor-

mant trees and plants) use respectively about 2⅓ and 1⅔ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases, after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will be required, as the kerosene will combine readily with the naphtha soap, in water, when thoroughly agitated. Double the quantity of naphtha soap given in the above formula, however, will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard," this should first be broken with a little caustic potash or soda, as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene, or rain water may be employed.

*Crude petroleum emulsion.*—Crude petroleum emulsion may be prepared in identically the same way as described for kerosene emulsion, substituting crude petroleum for kerosene. The grade of crude petroleum employed in the East is that known as "insecticide oil," having a specific gravity of 43° to 45° Baumé. The same dilutions for winter and summer spraying should be observed as stated for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

*Whale-oil soap wash.*—There are several brands of whale-oil soap on the market. Potash soap is preferable, and it should not contain over 30 per cent of water. For spraying dormant trees the soap is dissolved in hot water at the rate of 2 pounds to each 1 gallon, and spraying should be done before the wash cools, otherwise it is forced through the nozzle with difficulty. For spraying trees in foliage use the soap at the rate of 1 pound to 3 or 4 gallons of water, or even weaker.

*Lime-sulphur wash.*—Lime-sulphur has become the main reliance in spraying orchards infested with the San Jose scale, and is effective in controlling numerous other insects and is valuable for certain fungous troubles. The following formula is used only on dormant trees:

| | | |
|---|---|---|
| Stone lime | pounds | 20 |
| Sulphur (flour or flowers) | do | 15 |
| Water to make | gallons | 50 |

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for an hour, when the final dilution may be made, using either hot or cold water, as is most con-

venient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray pump or tank. The wash may be cooked in large kettles or preferably by steam in barrels or tanks.

*Miscible oils.*—Under the head of miscible oils are designated several commercial insecticides coming into considerable use as sprays for scale insects during the dormant period of the trees, and their use will often be advantageous, especially where but a few trees are to be treated. Miscible oils should be used on dormant trees at the strength recommended by the manufacturers.

*Commercial lime-sulphur washes.*—There are on the market several brands of concentrated lime-sulphur solutions, designed to replace the homemade lime-sulphur wash, mentioned above. These washes in general have proved to be satisfactory for the control of the San Jose scale, and will doubtless be about as effective against the oyster-shell and scurfy scales as the homemade wash, the preparation of which may thus be avoided if desired. These may be used on dormant trees, or, much more dilute, on trees in foliage.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *March 30, 1910.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE STATUS OF THE COTTON BOLL WEEVIL IN 1909.[a]

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### AREA INFESTED.

All the regions in which the cotton boll weevil was known to occur in 1909 are shown on the accompanying map (fig. 1). It will be noticed

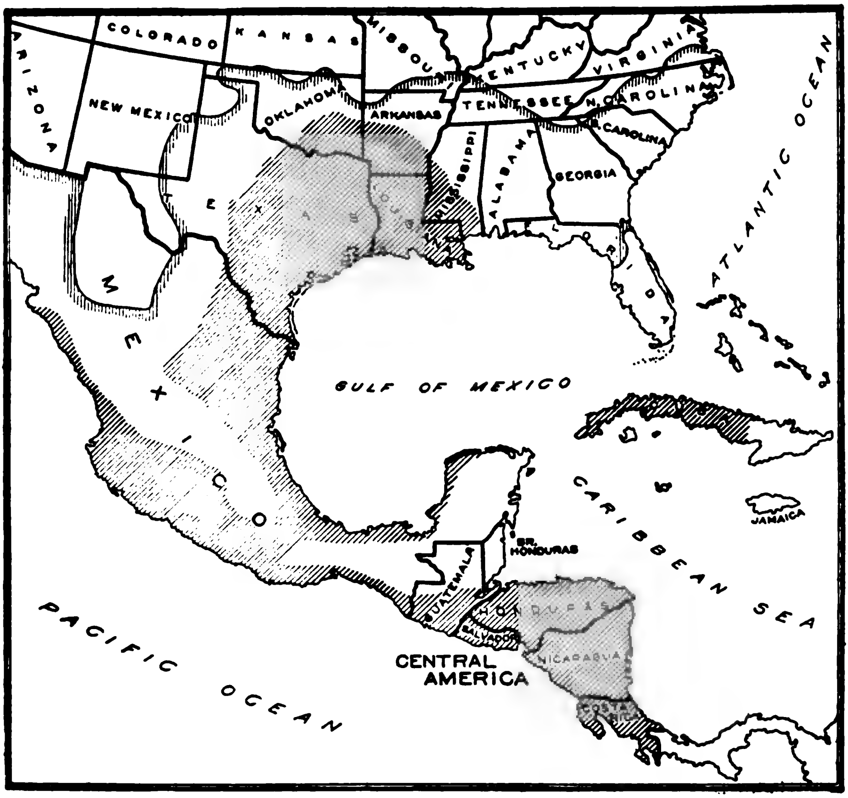


FIG. 1.—Map showing the regions in which the cotton boll weevil occurred in 1909.

that outside of the United States the insect occurs only in Mexico, Central America, and Cuba. The infested area in Texas covers all

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[a] The statements in this circular regarding the territory infested by the boll weevil cover the advance made by the insect up to the close of the year 1909. Since that time it has extended its range in the United States considerably, as will be shown in a map soon to be issued by the Bureau of Entomology.

except the western cotton-producing counties, which in recent years have contributed increasingly to the crop of the State. Practically all of the State of Louisiana is within the infested territory. In Mississippi, 23 counties are more or less infested; in Arkansas, 20; and in Oklahoma, 15. Of the total cotton acreage in the States concerned, the weevil is found in about 80 per cent in Texas, 30 per cent in Arkansas, 25 per cent in Mississippi, 35 per cent in Oklahoma, and practically 100 per cent in Louisiana. This area comprises very nearly 30 per cent of the cotton acreage in the United States in the year 1909, or about 37 per cent of the total number of square miles found within the cotton belt. In other words, a portion of the infested territory includes relatively a greater acreage devoted to cotton than the remainder of the belt.

It is important to note that along the extreme outer edge of the infested territory in the United States the weevils did not invade the cotton fields until late in the season of 1909; too late, in fact, to do any damage to the crop of that year.

The infested area includes many regions in which the boll weevil problem takes on local aspects. There is the greatest diversity of climatic and other conditions which react on the insect in such a way as to establish areas of varying degrees of damage. These individual areas will not, of course, display a constant amount of damage each season, but in a series of years will show features that serve to differentiate them from each other. In general, the damage is least on the dry plains of the western portion of Texas and increases toward the east. Where a large precipitation is combined with the presence of an abundance of timber, as in portions of Louisiana, the damage is greatest.

Nothing has transpired up to the present time to indicate that the weevil will not eventually reach the northernmost and easternmost portions of the cotton belt. Its advance to the east will be more rapid than to the north. This is on account of the lower temperature in the north, to which it seems necessary for the weevil to adapt itself more or less slowly. In some seasons the northward advance will probably be checked altogether by abnormal conditions, but the experience now acquired seems to indicate that the weevil will eventually overcome any climatic barriers that may be encountered. Although the advance to the east and north seems to be certain, there is a large region in the west into which the weevil can make its way only with very great difficulty, if at all. In the high, open plains of western Texas, where cotton production has developed enormously in the last ten years, the conditions of the winters and summers combined will probably serve as an effective barrier against the weevil. In that region there is little timber in which the insects may obtain shelter from the severe winters. Moreover, the normal

dryness of the summer compared to that in more easterly regions, causing small plants and little shade, will act as an equally strong check upon the insect. On account of these conditions it can not be considered that the boll weevil is an important menace to the cultivation of cotton in the territory west of about the one-hundredth meridian.

## FEATURES OF THE SEASON OF 1909.

The season of 1909 was very peculiar as regards damage by the boll weevil. The preceding season (1908) was also abnormal, but in quite a different way. The two abnormal seasons coming in succession have naturally given rise to various erroneous ideas about the future.

The situation in 1908 was affected first by climatic conditions of the fall of 1907 and the following winter. These allowed an unusually small number of weevils to pass through the winter. Experiments performed with many thousands of weevils in large field cages showed a survival of about 3 per cent as against 12 per cent after the winter preceding the season of 1907. That is, about four times as many weevils survived to damage the crop in 1907 as in 1908. The records based upon experimental cages were corroborated by the inspection of about 300 fields in June, 1908. From this work it was found that in the representative fields examined there was an average of only 3 weevils per acre in northern and eastern Texas in 1908 as against 226 per acre in 1907. In August, 1908, an examination of the degree of infestation of squares in many localities showed 5 per cent damage as against 54 per cent in 1907.

Following the remarkably disastrous conditions for the weevil in 1908 in Texas came another series of checks in 1909 in Texas in June, August, and September. This was the more important because the pest had not had sufficient time to recover from the loss suffered in 1908. It has been pointed out elsewhere that the most important check to the weevil in Texas is dry weather. It has been found that the damage done is practically in proportion to the amount of precipitation during the growing season. As the rainfall increases the damage becomes greater. The season of 1909 in Texas will always be notable on account of the extremely dry and hot weather. At Fort Worth there was a monthly deficiency in rainfall from February to June, inclusive, of over 1 inch. The accumulated deficiency for the first seven months in the year was 10.42 inches. It must be recalled that this represents practically a third of the normal total annual rainfall at Fort Worth. Other points in the portion of Texas where the bulk of the crop is produced show similar records. At Dallas, for instance, the accumulated deficiency of the year 1909 up to August 1 was 14.28 inches, for Waco 10.98 inches, for Palestine 13.03 inches, and for Taylor 11.28 inches. In addition to the actual shortage in rainfall very high temperatures occurred. The drought without the high temperatures, or vice versa, would not have affected the weevil especially. The two influences

combined, however, served to give it such a check as it has never experienced in this country. At many points in Texas and Louisiana all records for summer temperature were exceeded. For several days the thermometer registered over 110° F. and in some cases 114° F. was reached. On the surface of the ground the temperature was naturally even higher.

No one who traveled in Texas during the season of 1909 could have failed to notice the effect of the abnormal climatic conditions on crops of all kinds. The cotton generally grew to from one-fourth to one-half of the normal size. The conditions were so adverse that even variety characteristics were more or less obliterated. The same conditions acted on the boll weevil. In fact, through large productive areas in central and northern Texas the insect was so reduced in numbers that it did not injure the crop to any extent whatever.

It is interesting to note that the experience of the season of 1909 shows conclusively that while a certain degree of dry weather is greatly to be desired for the controlling effect it has upon the boll weevil, dryness beyond a certain degree not only affects the boll weevil adversely, but also the cotton plant. In fact, it became evident that the cotton plant was so stunted by the dryness that it was unable to derive any advantage whatever from the comparative scarcity of the weevils.

### DISPERSION OF 1909.

As regards dispersion, the season of 1909 was almost as unusual as in other respects. In one region by far the largest advance ever recorded was made by the weevil. This covered 120 miles of territory in southern Mississippi. At the same time in Oklahoma the greatest advance was only 30 miles, while throughout the greater portion of that State the line was extended only about 10 miles. A notable feature of the year's dispersion was the failure of the insect to extend its range considerably into the Yazoo Delta in Mississippi. During the preceding year an exceedingly light infestation reached the extreme southern portion of the delta. This was the vanguard of a flight that was rather extended. During the season of 1909 the insect extended its range in that quarter only about 15 miles. Why there should be an advance of 120 miles in southern Mississippi and only 15 in the northern portion of the State at first seems obscure, but studies that have been made indicate the explanation very clearly. One of the primary reasons for the dispersion movement of the weevil seems to be its inclination to obtain fresh food, and cotton squares in which to breed. Where the cotton fields are small and separated by considerable distances, this instinct causes the weevils to fly over a large extent of territory. On the other hand, where cotton fields are numerous it is unnecessary for a considerable advance to be made. In other words, a region of light

cotton production causes the dispersion movement to be spread over more territory, while a region of heavy cotton production absorbs the weevils that are compelled to fly away from the locality in which they were produced. This undoubtedly explains in part the failure of the weevils to make a heavy advance into the Yazoo Delta during the season of 1909. Moreover, there is at least one further reason for the situation described. The number of weevils that enter into the dispersion movement must naturally be dependent upon the numbers that are bred in the cotton fields of the region from which the dispersion takes place. A heavy infestation in a certain region, therefore, means a large number of weevils to fly into previously uninfested territory. In a contrary way a light infestation means a comparatively small volume of weevils to fly beyond the original territory. In northeastern Louisiana, the locality from which the Yazoo Delta must naturally become infested, various conditions caused an unusually small number of weevils to be found in the fall of 1909. In fact, the number was not sufficient to cause a heavy dispersion movement. It is impossible to state which of these factors is more important, but in all probability the small number of weevils in northeastern Louisiana and the extensive cotton fields of the delta which absorbed the light movement were about equally important in preventing a further advance in the Yazoo Delta than was made in 1909.

## HISTORY IN TEXAS.

Naturally the status of the boll weevil is shown by its history in the region in the United States where it has existed for the longest time. It is therefore important to examine the history of the insect in Texas. On account of great climatic variations, for the purpose of determining the manner in which the boll weevil has affected cotton production in Texas it is necessary to divide the State into three areas. These are eastern, central, and western Texas. The divisions are made in accordance with variations in normal annual precipitation and other factors. Eastern Texas as used in this circular is bounded on the west by a line running practically north and south from the western line of Lamar County to the western line of Brazoria County. In this region the rainfall is 45 inches per year or more. It comprises the counties listed below.[a] Practically the whole area is covered with forests. It covers 40,180 square miles. Central Texas comprises a broad belt from the Gulf to the Red River, beginning on the west with the limit of the belt of 32 inches normal annual rainfall, and extends eastward to the line just described as defining the

[a] Red River, Bowie, Franklin, Titus, Morris, Cass, Wood, Camp, Upshur, Marion, Harrison, Smith, Gregg, Cherokee, Rusk, Panola, Nacogdoches, Shelby, San Augustine, Sabine, Angelina, Trinity, San Jacinto, Polk, Tyler, Jasper, Newton, Liberty, Hardin, Orange, Jefferson, Chambers, Galveston, Lamar, Delta, Hopkins, Rains, Van Zandt, Henderson, Freestone, Anderson, Leon, Houston, Madison, Waller, Grimes, Walker, Montgomery, Harris, Fort Bend, and Brazoria.

western boundary of the eastern Texas area. Central Texas consists of 45 counties[a] and comprises 38,868 square miles. It is for the most part prairie country, although there are wooded valleys and occasional strips of timbered uplands. Western Texas comprises the remainder of Texas, beginning with the line marking the end of the area of 32 inches normal annual precipitation. It is largely a prairie region, though wooded valleys are numerous. Another factor in differentiating western Texas from central Texas is the increased elevation.

A careful study has been made of the manner in which the weevil has affected the production of cotton in the three regions mentioned. Use has been made of the census records of production from 1899 to 1909, a period of eleven years, as shown in the accompanying table:

*Eastern, central, and western Texas cotton production compared, 1899–1909, from United States Census.*

[500-pound bales.]

| Years. | Eastern. | | Central. | | Western.[a] | |
|---|---|---|---|---|---|---|
| | Bales. | Per cent of Texas crop. | Bales. | Per cent of Texas crop. | Bales. | Per cent of Texas crop. |
| 1899 | 637,872 | 22.44 | 1,633,618 | 62.61 | 337,528 | 12.94 |
| 1900 | 811,413 | 23.59 | 1,892,660 | 55.04 | 734,304 | 21.36 |
| 1901 | 633,620 | 25.32 | 1,448,872 | 57.90 | 419,674 | 16.77 |
| 1902 | 736,660 | 29.48 | 1,332,487 | 53.34 | 428,866 | 17.17 |
| 1903 | 545,288 | 22.06 | 1,242,654 | 50.28 | 683,139 | 27.64 |
| Average, 1899–1903 | 672,970 | 24.88 | 1,510,060 | 55.85 | 520,702 | 19.26 |
| 1904 | 720,671 | 22.91 | 1,700,224 | 54.15 | 724,475 | 23.07 |
| 1905 | 329,523 | 12.96 | 1,414,115 | 55.63 | 798,294 | 31.40 |
| 1906 | 672,497 | 16.11 | 2,213,863 | 53.03 | 1,287,846 | 30.85 |
| 1907 | 343,328 | 14.92 | 1,218,143 | 52.95 | 738,708 | 32.11 |
| 1908 | 515,038 | 13.50 | 1,980,766 | 50.60 | 1,318,681 | 33.65 |
| 1909 | 474,311 | 18.80 | 1,362,096 | 53.99 | 686,404 | 27.20 |
| Average, 1904–1909 | 509,228 | 16.53 | 1,648,201 | 53.39 | 925,735 | 29.72 |

[a] Including counties grouped by census under "All other."

In eastern Texas the production for five years ending with 1903 averaged 24 per cent of the total crop of Texas. During the same series of five years western Texas averaged 19 per cent of the total crop. For the six years ending with 1909 the eastern Texas production dropped to 16 per cent of the total crop of Texas, while the production in western Texas advanced to 29 per cent of the total crop in Texas. In other words, the portion of the Texas crop produced in one area has decreased 24 per cent and in the other it has increased 74 per cent. This increase in the west, where the dry climate reduces boll-weevil injury, served to offset the loss in eastern Texas, and

[a] Central Texas counties: Cooke, Grayson, Fannin, Denton, Collin, Hunt, Tarrant, Dallas, Rockwall, Kaufman, Johnson, Ellis, Bosque, Hill, Navarro, McLennan, Limestone, Bell, Falls, Williamson, Milam, Robertson, Brazos, Travis, Lee, Burleson, Washington, Hays, Bastrop, Caldwell, Fayette, Colorado, Austin, Guadalupe, Gonzales, Lavaca, Wharton, Dewitt, Goliad, Victoria, Jackson, Refugio, Calhoun, Matagorda, and Aransas.

thus accounts to a great extent for the fact that the total crop of the State has not fallen off.

The table is introduced to show in what manner the State of Texas is able to produce large crops of cotton since the advent of the weevil. There has clearly been a falling off in the proportion of the total crop of the State which east Texas produces. While this has happened an extensive immigration into western Texas, where the weevil is unable to withstand the climatic conditions, has resulted in a production which more than offsets the loss suffered in the eastern part of the State.

The great increase in production in the western portion of Texas is shown conspicuously by reference to individual counties. In 1899 Hall County, in the extreme western portion of the State, produced 113 bales; in 1908, over 17,000 bales. Between the same years the crop in Jones County increased from 4,000 bales to 33,000; in Taylor County, from 6,000 to 37,000; in Coleman County, from 8,000 to 62,000; and in Runnels County, from 3,000 to 56,000. There was an average annual gain in the period referred to in Hall County of over 10,000 bales; in Jones County, an average annual gain of over 22,000 bales. The other counties in that portion of the State show similar records.

While this remarkable increase has been accomplished in western Texas, there has been a great falling off in the eastern portion of the State. For instance, Fannin County produced 59,000 bales in 1899 and 48,000 bales in 1908. Likewise, in the same time Red River County fell from 29,000 bales to 18,000 bales. These conditions are better illustrated by comparing the average annual production before 1904 and since that year. This gives a period of ten years, in half of which the boll weevil was distributed generally in eastern Texas. For the five years ending with 1908, the crop of Fannin County showed an average annual loss of 16,752 bales; Lamar County, an average annual loss of 10,246 bales; Red River County, of 11,576 bales; and Grayson County, of 10,174 bales.[a]

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[a] The Bureau of Plant Industry attributes the reduction in cotton production in east Texas to the following causes, in addition to the boll weevil:

First. The construction of railroads and sawmills in the long-leaf pine counties, which, by their higher wage, drew their main supply of labor from the small farms of that section.

Second. The introduction of more profitable lines of agriculture, such as wrapper tobacco, truck gardening, small fruits, peaches and pears, for which east Texas is well adapted.

Third. The Texas coast rice industry, which in the past decade increased over 2,000 per cent and attracted many small farmers from east Texas.

Fourth. The general effort made by the United States Department of Agriculture to induce the farmers to raise their home supplies, which has had considerable effect.

This readjustment of agriculture in east Texas by a reduction of the acreage in cotton and the adding of other staple and cash crops would, however, have taken place in any event. It was simply hastened by the advent of the weevil.

Mr. F. W. Gist, of the Bureau of Statistics of this Department, has made a very careful study to determine the center of cotton production in Texas for each year from 1899 to 1908. As would be supposed from the figures that have been given, it was found by Mr. Gist that the center of production had moved considerably to the westward. In fact, this center moved from 30.78 miles east of the ninety-seventh meridian in 1899 to 19.14 miles west of this meridian in 1908. This was a westward movement of practically 50 miles. The center of production in 1899 was on a line passing north and south through the eastern portion of Grayson County, in Texas. In 1908 the center had moved to a line passing parallel with the other through the western portion of Cooke County, in Texas.

The situation in central Texas is most interesting. This area in the five-year period ending with 1903 produced 55 per cent of the Texas crop. For the six-year period ending with 1909 it produced 53 per cent of the Texas crop. This shows that for practical purposes the production in the central portion of the State has been maintained in spite of the weevil. This has been very largely due to the efforts that have been put forth by the Department of Agriculture, and indicates that in central Texas the control of the weevil for practical purposes is an accomplished fact.

In this connection attention may be directed to the fact that there is a tendency to attribute to the boll weevil more damage than is rightly chargeable to the insect. Climatic conditions, changes in acreage, and other factors, including the work of the bollworm and leaf worm, caused great variations in production in any locality, from year to year, before the advent of the boll weevil. Careful allowance must be made for the effects of such factors in determining the extent to which the boll weevil has affected the crop. In the statements made in this paper a careful attempt has been made to avoid overestimating the effect on the crop due to the boll weevil.

### THE CHAIN CULTIVATOR.

Though not perhaps strictly connected with the status of the weevil, the opportunity is taken to discuss briefly an important machine for use in weevil control. As the result of many examinations to determine the natural mortality of weevils in cotton fields, it was found that when infested squares fell to the middles, where they were exposed to the unobstructed rays of the sun, the great majority of the weevils perished in a remarkably short time. Under natural conditions the bulk of the squares fall in the shade of the plants. Therefore attempts were at once made to devise a machine that would carry the infested squares from shaded areas to the middles, where they would be exposed to the sun. After a great deal of study and experimentation Dr. W. E. Hinds, now professor of

entomology in the Alabama Polytechnic College, perfected a device that has been found to accomplish this work in a very satisfactory manner. It consists of two series of chains arranged on a wheelless carriage in such a way that the anterior ends pass close to the base of the plants, while the opposite extremities pass about midway between the rows. The inner posterior ends of the chains approach within about 8 inches of each other. As this machine is pulled through the field the great majority of the squares are dragged to the middles and deposited in a narrow row. In addition to the work of placing the squares where they will be acted upon by the sun, the chain cultivator has been found to have an exceedingly important cultural effect. It destroys small weeds, reduces clods, and fills the cracks. In fact, it establishes a dust mulch, which is greatly to be desired in cotton culture.

An experiment performed in 1908 showed the effects of the practical use of this machine. Half of a small field was cultivated in part by the chain cultivator and the remainder in the usual manner. The yield was increased by 131 pounds of seed cotton per acre where the machine was used. This amounted to a gain per acre of $3.93, or practically what the machine can be manufactured for. No extra labor was involved in the use of the machine, since its use merely replaced the use of the ordinary implements for the later workings of the crop. This experiment shows in a practical way the usefulness of the machine, which should eventually come into common use as much for its cultural effect as for weevil control. It is the direct result of strictly investigational work. The inventor of this machine surrendered all his rights as to royalties to the Department of Agriculture, so that its manufacture may be taken up by any individual or company without the payment of fees to anyone whatever.

The possible wide usefulness of the chain cultivator was appreciated by one of the largest implement concerns of the United States, which undertook the manufacture of 100 of them to be distributed during the season of 1909. Several practical tests were made during that season, and they showed that the hopes for the implement were not too high. Many planters who have witnessed the operation of the implement are arranging to use it for corn as well as for cotton.

## PARASITES OF THE WEEVIL.

The insect enemies of the weevil are practically dependent upon it for food. Therefore any conditions that affect the weevil adversely over a large extent of territory also affect the parasites. On this account work of the insect enemies of the boll weevil in 1909 was not at all conspicuous. Nevertheless important advances were made in the studies of the practical utilization of these enemies of the weevil. One parasite that has attacked the weevil in Texas may have

extended its range to the Mississippi River, and another, hitherto apparently restricted to the eastern portion of Louisiana, has been found in Texas. There can be no absolute certainty that these species have actually extended their range, but at any rate they were found over unexpectedly large areas. The fact that they do not appear to be as restricted to certain regions as seemed at first to be the case undoubtedly serves to increase their potential importance as enemies of the boll weevil.

In spite of the most unfavorable conditions the parasites caused a considerable weevil mortality. The average total control of the boll weevil by its insect enemies throughout the season of 1909 was 16 per cent. This total is smaller than in preceding years, but this is clearly due to the adverse conditions in the infested areas that have been described. It is very noticeable that the work of the parasites in hanging squares was considerable. It ranged in Texas from 46 to 54 per cent. That is, nearly half of the weevil stages found in hanging squares were destroyed by natural enemies.

The work of the year added several species to the list of known insect enemies of the boll weevil. The list now includes 49 forms, of which 26 are parasites in the true sense—that is, dependent upon the boll weevil for furnishing food for their young, because their eggs are deposited upon the weevil—and 23 are predatory species, which merely devour the boll weevil but do not deposit their eggs upon or in it.

## IMPORTANT ADVANCE IN THE CONTROL OF THE BOLL WEEVIL.

During the season of 1909 a noteworthy advance was made in the control of the boll weevil by means of a poison. The credit for this achievement belongs to Mr. Wilmon Newell, of the State Crop Pest Commission of Louisiana. In experiments with Paris green for the destruction of the boll weevil, carried on in previous seasons, it was found that a certain number of the insects was killed. It occurred to Mr. Newell that the number reached by the poison could be increased greatly if a substance much finer than Paris green could be obtained. Arsenate of lead was the poison that was selected. Very large quantities of arsenate of lead may be applied to growing plants without any injury whatever. In the use of Paris green the presence of a small amount of free arsenic causes considerable damage to cotton plants if it is applied at the rate of as little as 5 pounds per acre. Mr. Newell succeeded in having an entirely new form of arsenate of lead made by one of the manufacturers of insecticides. The substance is an exceedingly fine powder that can be forced into the "buds" and even into the covering of the squares of the cotton plant to a far greater extent than a comparatively coarse powder like Paris green. The preparation of this form of arsenate of lead

consequently obviated two important difficulties that attended the use of Paris green; that is, the danger of burning the plants by large applications and the difficulty in forcing the substance into the parts of the plants where it would be taken up by the insect. Thus the foundation was laid for very greatly increasing the mortality that had previously been obtained from the use of another poison.

In 1909 the State Crop Pest Commission of Louisiana had thirteen experiments with powdered arsenate of lead, located at different places, comprising over 46 acres. The poison was applied at from 1 pound to 51 pounds per acre. In different experiments from one to ten applications were made. In all but one of these experiments an increased crop was obtained that resulted in a profit, after deducting the expense incurred, which varied from a few cents to $23 per acre. In the one experiment which did not result in a net profit an increased yield of 121 pounds of seed cotton per acre was obtained. The very large amount of poison used in this case (51 pounds per acre) involved such an expense that this increased yield was not sufficient to offset it. In the experiments in which from 10 to 23 pounds of the poison per acre were used in from five to seven applications, the net profit ran from $3.63 to $23.54 per acre. The most profitable amount of the poison to be used seems thus to be indicated, although the conclusions from the preliminary work may be changed as the result of future investigations.

It is important to note that the very encouraging results obtained by Mr. Newell were in experiments in which the application of the poison was made either by one of his representatives or under this representative's directions. A large part of the efficiency of powdered arsenate of lead seems to be due to the thoroughness of the application. It is therefore to be supposed that under the practical conditions obtaining on plantations it may not be possible to obtain as successful results as those in some of the experiments described.

It does not detract from the high value of Mr. Newell's discovery to state that all the experiments that have been performed indicate most clearly that powdered arsenate of lead is not an absolute specific for the weevil in the sense that it can be relied upon to the omission or neglect of other means of control. The early fall destruction of the cotton plants is undoubtedly a condition necessary to the successful use of the poison. Likewise, the other steps in the system of control advocated by the Bureau of Entomology are not minimized by the importance of the present discovery. At most the poison merely places another means of control at the command of the planter. Everything indicates that it will be an important means. The system of control in use has been to a certain extent a combination of expedients for avoiding damage rather than of ways of actually killing the weevils. In fact, the early fall destruction of the weevils by burning

the plants has been the only important and generally applicable direct means at the command of the planter. Powdered arsenate of lead is especially important as a direct means of killing weevils that may be applied at a season in which hitherto no important means of a direct nature have been available. Extensive work that is now being planned it is hoped will lead to definite recommendations as to the procedure to be followed in the use of the poison for the greatest possible profit under various conditions.

The most important difficulty that is likely to be encountered in the use of powdered arsenate of lead against the boll weevil is the possible deleterious effect of the poison in the soil. Recent investigations conducted in orchards in Colorado where spraying of arsenicals has been practiced for many years seem to indicate that a considerable amount of damage has resulted from the arsenic that has become lodged in the soil near the bases of the trees. In fact, Prof. W. P. Headden believes that in addition to the caustic effect of the arsenic on the roots of the trees there is a probability that damage is done the plants by absorption. At any rate, cases have been observed where the general health of the trees seems to have been affected in such a manner as would only seem likely to result from absorption. Although this matter is by no means fully understood at this time, it will be necessary to investigate carefully the possibility of injurious effects on cotton lands from repeated annual applications of such large quantities of powdered arsenate of lead as were found to be profitable in the experimental work in controlling the boll weevil. If the cumulative effect of these applications is at all considerable, the use of the poison can not be advised. At the same time there is a possibility that something may be done in the counteracting of the possible deleterious effects of arsenate of lead by the application of some material with the fertilizers.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *April 1, 1910.*

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Issued June 10, 1910.

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 123.
L. O. HOWARD, Entomologist and Chief of Bureau.

# METHODS OF CONTROLLING TOBACCO INSECTS.

BY

A. C. MORGAN,
*Agent and Expert.*

40704—10——1

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CIRCULAR No. 123. Issued June 10, 1910.

United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# METHODS OF CONTROLLING TOBACCO INSECTS.

By A. C. MORGAN,
*Agent and Expert.*

## INTRODUCTION.

Investigation by the Bureau of Entomology of the United States Department of Agriculture of insects affecting tobacco has been in progress in the "dark tobacco" districts of Kentucky and Tennessee since July, 1907.

In the work in Tennessee the Bureau of Entomology has had the hearty cooperation of the Tennessee agricultural experiment station and of its director, Prof. H. A. Morgan. During the summers of 1908 and 1909 Professor Morgan assigned a student, Mr. D. C. Parman, of the University of Tennessee, as an assistant to the Federal agent in charge of the tobacco-insect investigations. The writer wishes to express his thanks to Professor Morgan for the personal advice received from him and for this valuable cooperation.

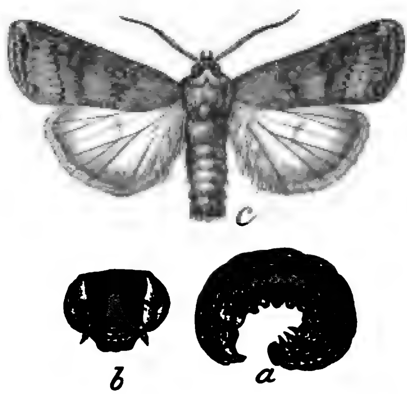


FIG. 1.—*Agrotis ypsilon*, one of the tobacco cutworms: *a*, Larva; *b*, head of same; *c*, adult. Natural size. (From Howard.)

In this investigation all insects found affecting tobacco have been studied, but particular attention has been given to the different species of cutworms, to the tobacco flea-beetle (*Epitrix parvula* Fab.), and to the tobacco hornworms (*Phlegethontius sexta* Joh. and *P. quinquemaculata* Haw.). In this particular circular only the insects mentioned above are considered. Although the investigation has not been completed,

it is thought that a description of remedies already in use, with the addition of those discovered during the investigation, may be of value to the growers.

It should be stated that the remedies herein treated will apply not only to Kentucky and Tennessee, but should apply equally as well to all tobacco-growing States which do not border on the Gulf.

## CUTWORMS.

Tobacco is frequently very seriously injured by various species of cutworms, of which two common species are illustrated in figures 1 and 2. It is the common experience of all farmers that cutworms are the most abundant and injurious on land that has been left uncultivated for some time previous to being planted to a certain crop. Where tobacco follows clover serious injury from these pests is likely to result. On the other hand, if winter grain precedes tobacco very little injury is likely to occur. However, if tobacco is to follow a clover sod it is a simple matter to rid the soil of these "worms." If it is possible to do so, the sod should be plowed under in the fall or winter and be kept free of vegetation by disking or harrowing. Thus by keeping the field free of vegetation the cutworms will be starved to death before the time for setting the tobacco. When sod land is plowed only a short time before setting the tobacco, a trap bait may be used to rid the field of the worms. In Farmers' Bulletin No. 120[a] Dr. L. O. Howard recommends thoroughly spraying a patch of weeds or clover with Paris green, then cutting it and dropping it in little bunches here and there throughout the field. Another trap bait that meets with wide favor is also recommended by Doctor Howard.[b] It

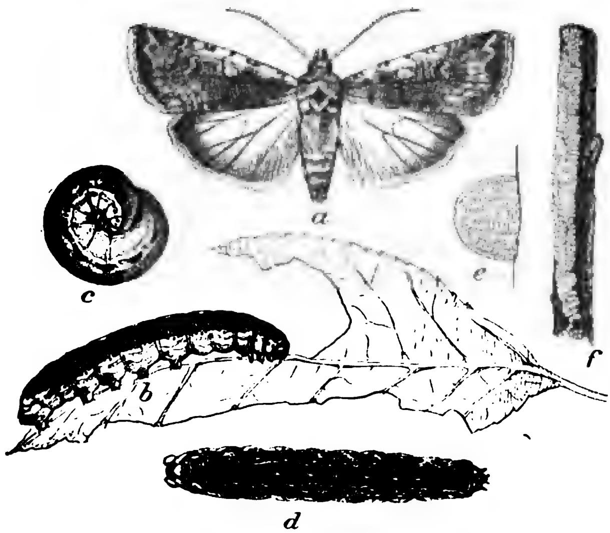

FIG. 2.—A tobacco cutworm (*Peridroma margaritosa*): *a*, Moth; *b*, normal form of larva, side view; *c*, same, in curved position; *d*, dark form of larva, from above; *e*, egg, from side; *f*, egg mass on twig. All natural size except *e*, which is greatly enlarged. (From Howard.)

[a] Farmers' Bulletin No. 120, United States Department of Agriculture, p. 23, 1900.
[b] Loc. cit.

consists of 1 pound of Paris green mixed with 50 to 75 pounds of bran, sweetened with molasses and moistened with water to make a mash. This should be dropped about the field three or four days before the plants are set, or two or three teaspoonfuls should be dropped about each hill after the plants are set. The cutworms are very fond of the sweetened mash and will generally eat it in preference to the plants. If seed beds should become infested with cutworms, the bran mash may be drilled through the bed and the ravages of the worms will be stopped. When trap baits are used great care should be exercised in keeping all live stock and barnyard fowls out of the field until the poisoned materials have been worked into the soil.

In the spring of 1908 the writer applied an arsenate of lead spray (made at the rate of 1 pound of arsenate of lead in paste form to 12 gallons of water) to a plant bed that was seriously infested with cutworms, with the result that all the cutworms were killed before they had done any appreciable additional injury to the plants.

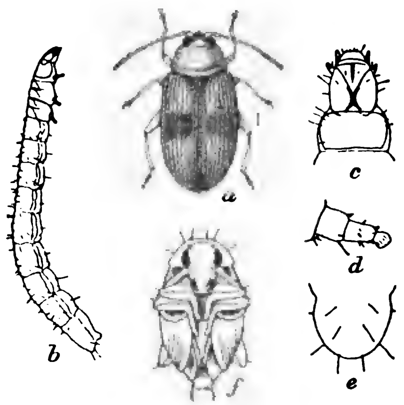

FIG. 3.—The tobacco flea-beetle (*Epitrix parvula*): *a*, Adult beetle; *b*, larva, side view; *c*, head of larva; *d*, hind leg of same; *e*, anal segment of same; *f*, pupa. *a*, *b*, *f*, Enlarged about 15 times; *c*, *d*, *e*, more enlarged. (From Chittenden.)

## THE TOBACCO FLEA-BEETLE.

(*Epitrix parvula* Fab.)

The tobacco flea-beetle (*Epitrix parvula* Fab.) (fig. 3) is known also by the common names of "tobacco flea" and "flea-beetle." It may be found, from setting time until frost, in more or less injurious numbers in every tobacco field in the United States. The most injurious outbreak on record occurred in the "dark tobacco" districts of Kentucky and Tennessee in the spring of 1907. Nearly all plant beds, except those tightly canvased, were devastated. Practically all the first sowing was destroyed and in many cases the second and third also. In consequence the acreage was reduced 15 to 20 per cent, and owing to the fact that the crop as a whole was set much later than usual an additional loss resulted. Late-set tobacco does not produce the same number of pounds as the early-set tobacco, and because of the lateness of harvesting and the near approach of cool weather this tobacco frequently cures poorly and is graded lower than tobacco that is harvested earlier in the season. The loss in Kentucky and Tennessee in 1907 was not far from $2,000,000.

The tobacco flea-beetle passes the winter in the adult stage in piles of dead leaves or dead grass in the woods, or in fence corners and

similar localities. The beetles begin to emerge from hibernation in Kentucky and Tennessee in March, generally about the time the young tobacco plants are appearing in the plant beds. The young and tender plants furnish a favorite food for the beetles, and unless the beds are well protected by canvas considerable damage is sure to result. The flea-beetle also seriously injures tobacco in the field. The writer has observed fields where numbers of plants were killed by its ravages. The young leaves were riddled with holes (fig. 4) and new foliage was completely devoured as fast as it appeared.

The tobacco flea-beetle occurs upon many species of solanaceous plants, as it has been found feeding upon tomato, potato, horse nettle, ground cherry, and "jimson weed" (*Datura stramonium*). It lays its eggs on or near the base of the stems of these plants and also upon the stems of young tobacco plants. The principal injury to tobacco is occasioned by the feeding of the adults upon the foliage, although

FIG. 4.—Leaf of young tobacco plant, showing work of the tobacco flea-beetle. (Original.)

the larvæ occasionally do considerable damage to the young plants by feeding upon the roots and stems.[a]

### PREVENTIVE MEASURES.

Properly canvased beds escaped uninjured in 1907. Only whole, strong canvas should be used, with boards or straight logs for the sides of the bed, banking up the earth 3 or 4 inches against the sides so that no holes are left beneath the logs, and fastening the canvas closely and securely to the sides. Beds canvased in this way will not suffer from flea-beetle attack.

[a] The biology of this insect has been carefully worked out by Dr. F. H. Chittenden in Bulletin No. 10, of this office, pp. 79–82, and in Bulletin No. 19, pp. 85–87.

## REMEDIAL MEASURES.

Even though flea-beetles do gain access to the plant beds in great numbers they can be controlled economically. Nearly all the severe loss of 1907 could have been averted had the growers known the proper remedy to apply. The writer has found the following insecticide very efficient in killing the beetles and not at all injurious to the plants:

| | | |
|---|---|---|
| Arsenate of lead (in paste form, or ½ pound powdered form) | pound.. | 1 |
| Water | gallons.. | 12 to 16 |

Mix the arsenate of lead thoroughly in a small quantity of water, pour into the tank, and add sufficient water to make the desired quantity; then apply to the bed with a spray pump until every leaf is thoroughly dampened. Two very good spray pumps are illustrated in figures 5 and 6. If a heavy rain falls soon after the application is made it may be necessary to make a second application; but it must be remembered that arsenate of lead will stick to the foliage much longer than Paris green, and will not be greatly dissipated by a light shower. After the plants have grown considerably it will be necessary to spray the bed again if flea-beetles are still numerous, for the new foliage will, of course, not be protected by the first application.

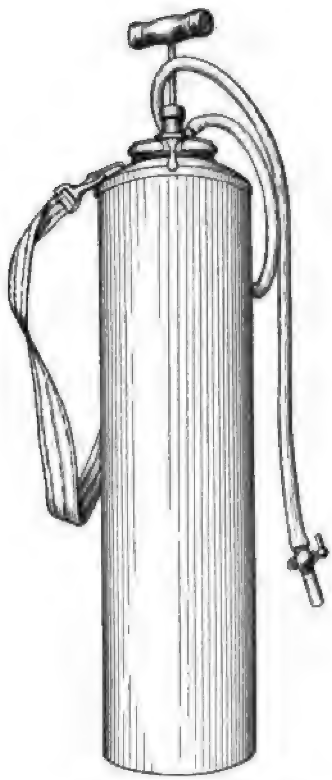

FIG. 5.—Compressed-air spray pump.

If flea-beetles are very numerous at the time of setting tobacco, the plants can be protected for several days by dipping the *tops*, just before setting, in the arsenate of lead spray recommended for use upon the plant bed. If plants are not dipped at setting time and if the flea-beetles appear in the fields in injurious numbers, apply the arsenate of lead, in the strength recommended above, with a knapsack sprayer (fig. 6). With this sprayer one man can spray from 5 to 6 acres of young tobacco in a day at a cost of from 25 to 35 cents an acre for arsenate of lead.

Tobacco growers as a rule pay too little attention to protecting their plant beds from insect attack. The result is that more of the

crop has to be set late than would be the case if the beds were protected. The grower should always be prepared to fight the flea-beetle, for often prompt attention to insect attack upon the plant bed will enable him to save his bed and thus be prepared to set all his crop early.

An early-set crop of tobacco has two very important advantages over a late-set crop. The first is the production of a better grade and of more pounds to the acre, as mentioned above. The second advantage is often more important than the first. An early-set crop will frequently mature in time to be cut before the August "shower" of tobacco worms is large enough to do it serious injury. This point will be explained more fully in the following discussion of the tobacco hornworms.

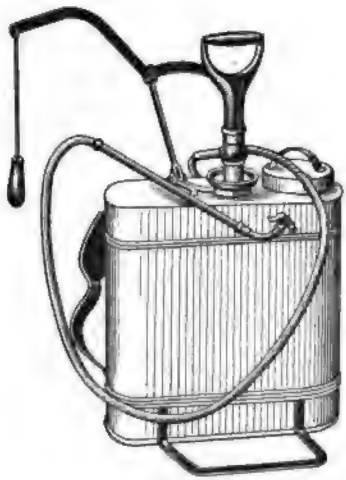

FIG. 6.—Knapsack spray pump.

**THE TOBACCO HORNWORMS.**

(*Phlegethontius sexta* Joh. and *Phlegethontius quinquemaculata* Haw.)

In the "dark tobacco" districts of Kentucky and Tennessee the hornworms are the most injurious tobacco insects, and they are important enemies of this crop in every district in the United States where it is grown. There are two species, the northern tobacco worm (*Phlegethontius quinquemaculata* Haw.) and the southern tobacco worm (*Phlegethontius sexta* Joh.) (fig. 7). The northern tobacco worm is called also the "Spanish worm" in Tennessee and Kentucky. This "worm," or larva, is in general darker than the southern tobacco worm, but the easiest way of distinguishing the two species is by the white markings on the sides of the body. The northern worm has 8 V-shaped markings on each side of the body, each of which incloses a spiracle, or breathing pore. The southern worm has 7 oblique lines on each side of the body, each of which passes in front of a spiracle.

DISTRIBUTION.

In general, as the common names indicate, the northern worm is most numerous in the north and the southern worm is most numerous in the south. The northern species is found as far south as Florida, though it is rare, and the southern species has been collected in Canada. At Washington, D. C., on the authority of Dr. F. H. Chittenden, the northern species predominates, while in Tennessee

the southern species is much the most abundant. These two species are so nearly alike in their work, life history, and seasonal history that the remedial measures which apply to one will apply equally well to the other. The life history and seasonal history notes given in this article are from observations upon the southern species (*Phlegethontius sexta* Joh.).

### LIFE HISTORY AND SEASONAL HISTORY.

This circular does not propose to describe in detail the life history and seasonal history of the tobacco worms, but to give only such data

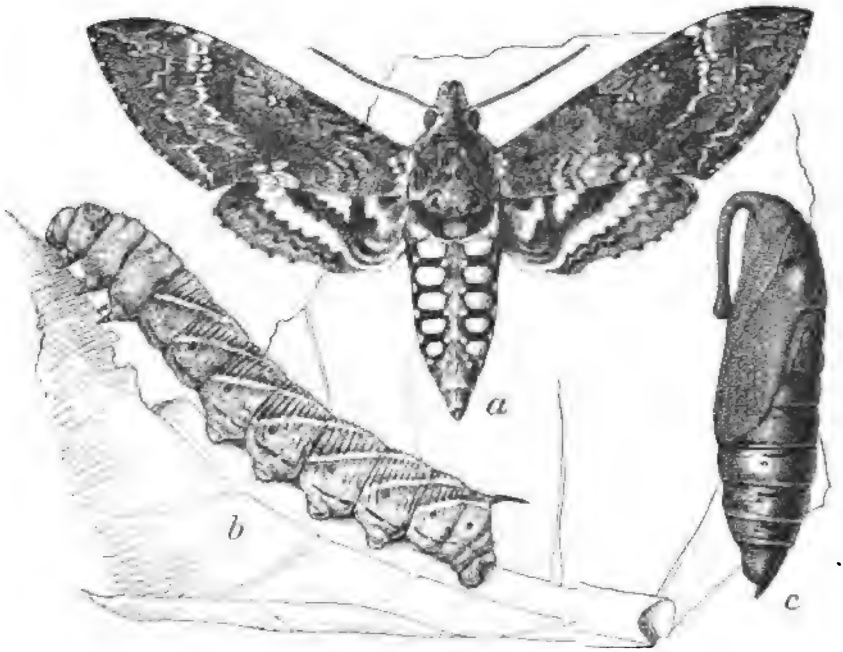


FIG. 7.—The Southern tobacco hornworm (*Phlegethontius sexta*): *a*, Adult; *b*, larva; *c*, pupa. (From Howard.)

as are necessary for the proper understanding of the reasons for recommending certain methods of control.

The tobacco moths begin to emerge from hibernation about June 1, and in a few days more they begin to deposit eggs. By reference to Table I it will be seen that the eggs hatch in about 4 days, and that the "worms," or larvæ, in from 19 to 20 days, pass through five stages of growth. They then enter the soil to pupate (fig. 8). Those that pupate not later than the last week of July will emerge in about three weeks as adult moths of the second generation, and will commence

depositing eggs in 3 or 4 days. Those that pupate after the 10th of August will usually hibernate, and will not emerge as adult moths until the following year. It is not until the third stage of growth—

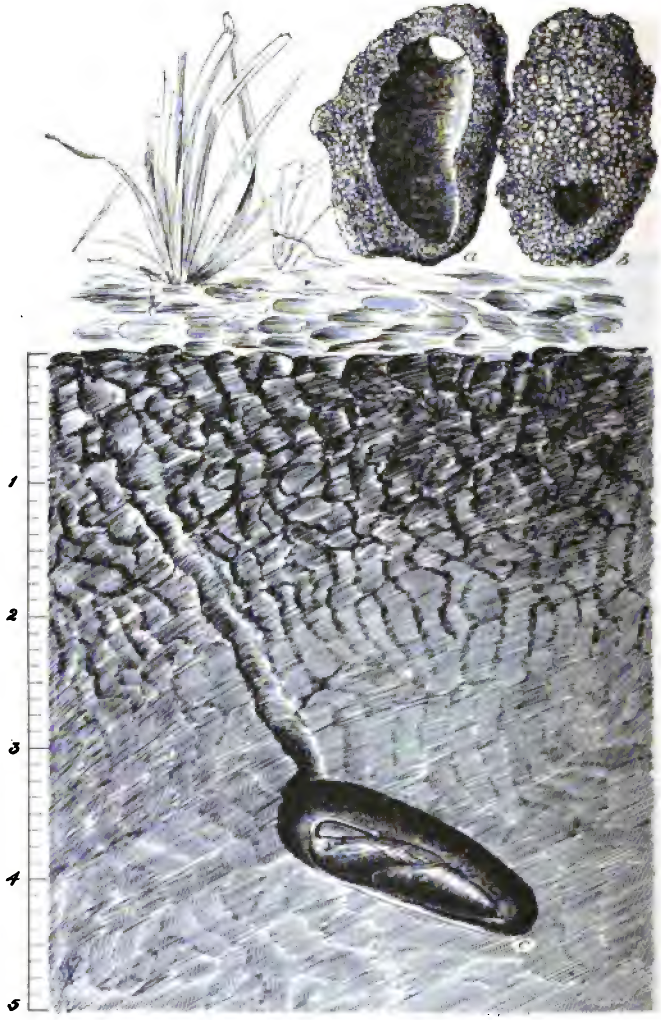


FIG. 8.—Hibernation of Southern tobacco hornworm: *c*, Pupa in hibernating cell in soil, at the depth at which pupation usually takes place in the stiffer soils; *a*, cross section of pupal cell viewed from below; *b*, pupal cell showing entrance hole of larva or "worm." Two-thirds natural size. (Original.)

that is, about 10 to 12 days after the eggs are deposited—that the larvæ injure tobacco seriously. In the fourth (fig. 9) and fifth stages one larva will ruin a small leaf of tobacco in a single day.

TABLE I.—*Average length of different stages in life history of the southern tobacco hornworm (Phlegethontius sexta).*

| Emergence of moth to oviposition. | Incubation period. | Instars, or stages, in growth of larva. | | | | | Total larval period. | Pupal period. | Total life cycle. |
|---|---|---|---|---|---|---|---|---|---|
| | | First. | Second. | Third. | Fourth. | Fifth. | | | |
| *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| 4 | 4 | 3 | 3 | 3 | 4— | 6.5 | 19.5 | 21 | 48 |

The tobacco moths, as has already been stated, begin to emerge from hibernation about June 1, or slightly earlier, and the *emergence continues until the middle of August or later.* From Table I we see that 48 days after the emergence of the moths from hibernation the moths of the second generation will become adult, and that in 4 days more they will begin to deposit eggs. These eggs will hatch in 4 days, and in 6 or 7 days more—that is, in about two months from the emergence of the first moths from hibernation—the larvæ of the second generation will pass into the third instar, the instar in which they begin to injure tobacco seriously. For example, let us take 4 moths that have emerged from hibernation on the following dates: June 1, June 15, July 1, and July 15. The second generation of tobacco worms, the progeny of these moths, will begin to injure tobacco seriously about August 1, August 15, September 1, and September 15, respectively.

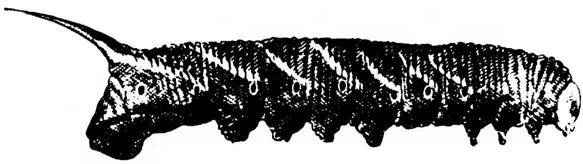

FIG. 9.—The Southern tobacco hornworm: Larva, fourth instar. Natural size. (Original.)

Although moths of both the first and second generations are depositing eggs during late July and in August, we will show later that by far the greater percentage of them has just emerged from hibernation, and belongs, therefore, to the first generation. This fact has a very important bearing upon the recommendation of fall plowing.

Tobacco worms begin to enter the soil to pass the winter (i. e., hibernate) about the middle of August, and continue doing so until frost. Usually they penetrate the soil to a depth of from 3 to 6 inches. Several observations upon "second bottom" soils of the Cumberland River have shown the average depth to be 4 inches; that is, to nearly the greatest depth to which the land was plowed in pre-

NOTE.—For the purposes of this article the date of oviposition may be considered as taking place at any time from June 1 to July 15, for there will not be a second generation from eggs deposited after the latter date.

paring it for the tobacco crop. After the larvæ, or "worms," have reached this depth they twist and turn many times, finally forming by this action oval cells, in which in a few days they transform to the hibernating form, or pupæ (fig. 8). The cells protect the pupæ much better from changes in the weather conditions than if the soil were lying in close contact to them. The insects remain as pupæ in the cells during the winter and, as has been stated, begin to emerge about the 1st of the following June as adult moths ready to deposit eggs upon tobacco.

### EMERGENCE OF THE SOUTHERN TOBACCO HORNWORM FROM HIBERNATION.

Careful records of the emergence from hibernation of the moths of the southern tobacco worm (*Phlegethontius sexta*) were kept during the seasons of 1908 and 1909 with very interesting results. In 1908 the emergence began about the last of May and continued until August 13. In 1909 the emergence began June 1 and continued until August 22, a period of 83 days. The records of 1908 were from an emergence of 58 moths. The records of 1909 were taken from an emergence of 1,667 moths, and are, therefore, of more value than the records of 1908. The most interesting part of the data is the fact that in both years a large percentage of the moths issued after midsummer. Table II shows the most important data obtained from the emergence records.

TABLE II.—*Record of emergence of tobacco moths from hibernation.*

| Period of emergence. | Emergence during period. | Period of emergence. | Emergence during period. |
|---|---|---|---|
| 1908.[a] | *Per cent.* | 1909.[b] | *Per cent.* |
| June 1 to July 15 | 34.5 | June 1 to July 15 | 22.7 |
| July 16 to August 13 | 65.5 | July 16 to August 22 | 77.3 |
| July 21 to July 31 | 52 | July 29 to August 9 | 50 |
| July 21 to August 13 | 63.8 | July 29 to August 22 | 59 |

[a] Emergence began about June 1. [b] Emergence began June 1.

From Table II it will be seen that there was a large wave of emergence in 1908 in the 11 days from July 21 to July 31, inclusive, and that 52 per cent of the total emergence took place during that period. The record further shows that after July 15, 5 per cent of the total emergence took place. In 1909 the results were very similar. The large wave of emergence took place during the 11 days from July 29 to August 9, inclusive, and 77.3 per cent of the emergence occurred after July 15.

### REMEDIAL MEASURES.

It has been the belief that the larger percentage of the tobacco worms that appear in late July and in August and September are of the second generation. This is not true, for nearly all the worms

that appear before the middle of July are killed by hand worming, and we have already shown by means of the life-history records that it will be two months from the emergence of the hibernating generation before the "worms," or larvæ, of the second generation will be large enough to injure tobacco seriously.

The statement has been frequently made to the writer, and personal observation has convinced him of its truth, that no difficulty is experienced in keeping tobacco free of worms by hand worming until the middle of July or later. Therefore, if tobacco is not injured by worms until after the middle of July, the conclusion is that until that date very few large tobacco worms have escaped hand worming and that the second generation from those that have escaped will be a very small one. *By far the greater portion of tobacco worms that appear in late July and in August are the offspring of moths that have emerged from hibernation;* for the second generation of worms, the offspring from those worms that mature after July 15 will not be of sufficient size to injure tobacco seriously until about September 15. If tobacco has been set early the crop will be ready for the barn by this date and will, therefore, escape the second generation of worms.

### FALL AND WINTER PLOWING.

Numerous experiments in 1907, 1908, and 1909 have demonstrated that as a rule only about one-fourth of the tobacco worms that hibernate are able to survive the winter and become adult. A part of the mortality is due to parasites, but a greater part of it is due to the unfavorable weather. The hibernating period is, therefore, a very critical period in the seasonal history of the tobacco worm, and many of those that do survive this period must be greatly weakened. Hence, any artificial disturbance of natural conditions will produce an additional mortality. As has been stated, the hibernation period is passed in the pupal stage in an oval cell (fig. 8), about 4 inches below the surface of the soil.

The most simple method of disturbing the pupæ during hibernation is to disk or plow the land. Both methods were tried. It was found that the disk would reach only from 5 to 10 per cent of the cells, and that therefore little benefit could be derived from that treatment. *The experiments in plowing the land killed more than half the pupæ that would otherwise have passed the winter successfully.* The ground should be plowed to the same depth as it was in preparing it for tobacco, for many of the tobacco worms will go down to the hard soil to form the hibernating cell, that is, to the greatest depth to which the soil has been broken. Plowing will throw the pupæ and the cells up to or near to the surface, will break the cells in nearly all cases, and will place the pupæ in close contact with the earth, in

which condition they are most susceptible to changes in temperature and to other climatological changes.

A week or ten days should elapse between the time of cutting the tobacco and the plowing of the land, in order to give all larvæ that are in the soil time to change to the more helpless pupal stage. Plowing should be done as soon thereafter as possible, so that the pupæ will be exposed as long as possible to unfavorable conditions.

It is the practice in many localities of Kentucky and Tennessee to disk the land that has been in tobacco in preparation for the wheat that is usually sowed after the tobacco crop has been harvested. In some localities it is thought that disking tobacco land is a better preparation than plowing, for the reason that plowing loosens up the soil too deeply and that the wheat will freeze out more easily. Undoubtedly this may be true for some soils, that is, soils that contain little clay and do not, therefore, run together very compactly. There is, however, a large proportion of clayey soils in the Tennessee and Kentucky tobacco regions in which wheat should not freeze out easily. In fact, many farmers always plow their tobacco land in preparing it for wheat because they believe they obtain a better yield. Whether it is wise or not to plow tobacco land for wheat is a question that each farmer must decide for himself. But it is certain that plowing will cause the death of more than half the pupæ, while disking will kill very few. Upon the looser soils it would, perhaps, be better to change the rotation and to sow some crop other than wheat after tobacco.

### COMBATING TOBACCO HORNWORMS UPON GROWING TOBACCO.

If tobacco is planted early the hand worming, necessary to kill all worms that appear before the large emergence wave in late July (Table II), can be made incidental to other processes in the growing of tobacco, and will require very little additional time and labor. Usually, in addition to the cultivation with farm implements, tobacco will receive the following attention: Two hoeings, hilling, priming, and topping, and much of the early tobacco will be suckered. During these necessary operations it is very easy to discover and to kill the few tobacco worms that have appeared, but when the large wave of emergence appears, hand worming will be found very costly, and in some localities impossible because of the scarcity of labor.

When tobacco worms are numerous it will require an outlay of at least $8 to $10 an acre to hand-pick the worms, and frequently the outlay will exceed $10 an acre.

*Use of Paris green.*—After the appearance of the July and August "shower of worms" an application of Paris green with a dust gun (fig. 10) will be found to be the most economical means of combat. In Tennessee and Kentucky Paris green is generally applied without

a carrier, but the writer prefers to mix it with twice its weight of finely powdered air-slaked lime, for when the application is made without a carrier the cloud of dust from the nozzle of the dust gun is so thin that it is impossible to determine whether the application is being made evenly. On the other hand, if the Paris green is mixed with about twice its weight of lime, the cloud of dust from the nozzle will always show whether the gun is working properly, and a clogging of the tubes can be discerned instantly. *Apply the dust early in the morning when the dew is upon the plants and when there in no breeze.*

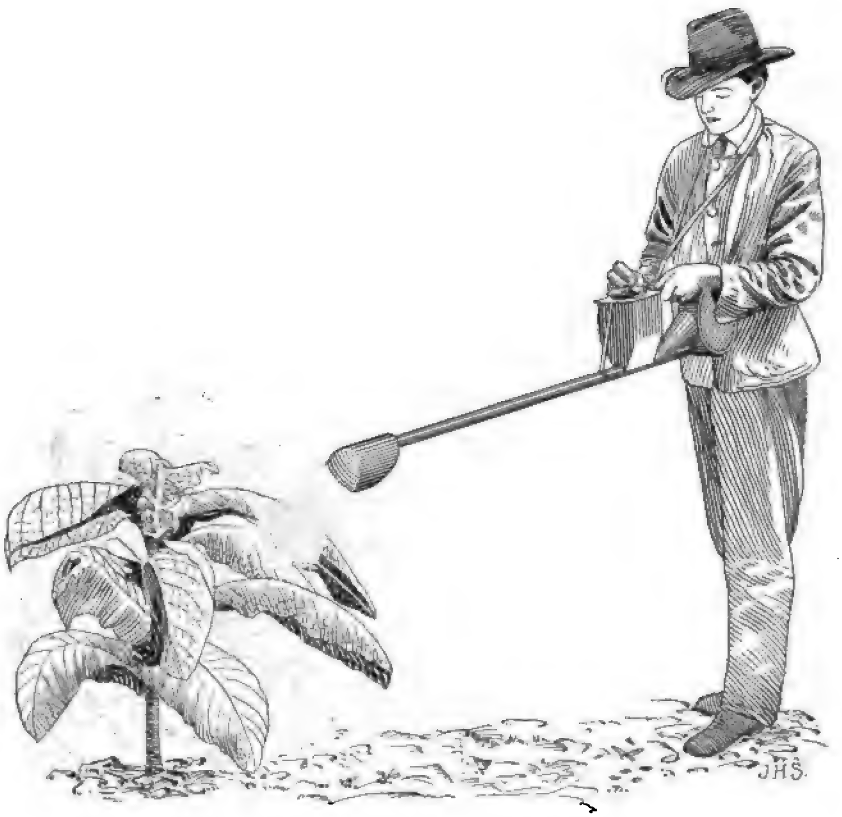


FIG. 10.—Applying Paris green to tobacco with a dust gun. (Original.)

Use a dust gun that has a strong fan power, and apply to only one row at a time. Great care should be taken to make the application even and thorough. No definite date can be given for making the first application. The time will depend upon the appearance of the young tobacco worms, and it may be the last week in July or not until about the middle of August. In 1908 and 1909 some of the early planted tobacco at Clarksville, Tenn., did not require poisoning, and in 1909 some of it required almost no worming. The first appli-

cation should be made within three or four days after the eggs begin to hatch. A thorough application of from three-fourths of a pound to 1 pound to the acre should be sufficient to kill the young larvæ. Do not wait until the worms become half grown before making the application, for in addition to being very much harder to kill than the young ones, they will do considerable damage to the leaves before they are killed. In dry weather a thorough application will remain effective for a week or ten days, but if there is a rain the application should be repeated immediately. The number of applications and the dosage will be influenced by weather conditions—whether wet or dry—by the numbers of young worms that appear, and by the earliness or lateness of the crop. By watching the effect of an application it can be easily determined whether it is losing its effectiveness and whether another application is necessary. The presence of a few large worms does not necessarily mean that the poison is ineffective. Some worms will escape the most careful applications, and these should be hand picked. The strength of the later applications upon tobacco that is nearly grown may be increased to 1, 1½, or even 2 pounds to the acre.

*Caution.*—Do not apply Paris green until two or three days have elapsed after suckering, for if a light rain should wash the Paris green into the fresh wounds made by breaking out the sucker, the caustic effect of the free arsenic may cause the leaves to drop off; also, do not apply a heavy dose of Paris green to tobacco when it is beginning to "grain," for the leaves are then more susceptible to "Paris green burn" than they are a few days previous to "graining."

*Spraying tobacco versus dusting.*—In this circular we have recommended dusting tobacco instead of spraying for two reasons: First, the labor of spraying is very much greater than that required to apply the dust. When tobacco is nearly full grown, that is, has begun to lap in the row, it will require from 120 to 150 gallons of water to spray an acre. Therefore, to apply the spray to 1 acre a 5-gallon knapsack sprayer must be refilled from 24 to 30 times. Second, the Paris green is not kept in suspension very easily in a knapsack sprayer and the last of the spray from the tank is likely to contain more than its proportion of the Paris green and thus cause injury to the plant. Furthermore, if great care is not used in applying the spray, a part of the plant is very likely to be drenched and the Paris green will be collected along the midribs and in the axils of the leaves in sufficient quantity to cause serious injury. It is not denied that a more even and thorough application can be made in spray form, but with negro labor, and with most white labor, we do not believe it will be made as satisfactorily as in the dust form.

*Arsenic left upon tobacco.*—There is fear among growers that if arsenicals are used a sufficient amount of arsenic may be left

upon the cured tobacco to injure the user. This fear is groundless. Prof. H. Garman,[a] state entomologist of Kentucky, reports the results of several experiments to determine the amount of arsenic left upon treated tobacco. Paris green was used at the rate of 1 pound to 160 gallons of water. The experimental row that received the greatest amount of Paris green received 8 sprayings with a total

FIG. 11.—Applying Paris green to tobacco with a knapsack spray pump. (Original.)

of 4⅓ pounds to the acre. The last spraying was made August 22, and the tobacco was cut September 4. Analysis of this tobacco showed 0.651 grain arsenious oxide to the pound. In the several experiments performed by Professor Garman only one experiment gave more than one grain of arsenious oxide to the pound of dried tobacco, and the tobacco in this experiment was sprayed the day it

[a] Bul. 63, Ky. Agr. Exp. Sta., pp. 69–74.

was cut. Professor Garman concludes that very little danger may be apprehended from the arsenic left upon tobacco. In 1909 the writer made several experiments to determine the amount of arsenic left upon tobacco. To make the test severe, arsenate of lead was used because this arsenical adheres to tobacco much longer than does Paris green. August 13 the experimental plat received a spraying at the rate of 5 pounds to the acre, and on August 18 a second spraying at the rate of 4 pounds to the acre. Arsenate of lead in dust form was used, hence the two dosages, amounting to 9 pounds, were almost exactly equivalent in the amount of combined arsenic to Professor Garman's dosage of 4½ pounds of Paris green. The tobacco was cut September 8. The analysis, made by the Miscellaneous Division of the Bureau of Chemistry, showed an average of 0.347 grain arsenious oxide per pound. Heavier dosages of powdered arsenate of lead left only 0.501 and 0.531 grain arsenious oxide per pound. A fatal dose of arsenic for an adult is about two-thirds of a grain, and this, of course, has to be taken into the stomach. Since tobacco is not taken into the stomach, and since so little arsenic will be taken into the mouth at any one time, it is not believed that there is the slightest danger in using tobacco that has been poisoned with either Paris green or arsenate of lead; in fact, the writer is personally acquainted with tobacco growers who have been applying Paris green to their tobacco for from six to eight years and who have been chewing and smoking the cured tobacco without injurious effects.

### POISONING THE TOBACCO MOTHS.

The custom of poisoning "jimson" blooms with arsenide of cobalt (flystone) to kill the tobacco moths when they feed has long been recommended and has been practiced in nearly every tobacco region, but unfortunately the custom has fallen into disuse. This method of combating tobacco moths should be revived, for the killing of one female moth at "jimson" blooms will be equivalent to the killing of several hundred worms later.

The following is the formula for this poison:

| | | |
|---|---|---|
| Arsenide of cobalt (flystone) | ounce.. | 1 |
| Water | pint.. | 1 |

Sweeten, just before using, with molasses or honey. Place a few drops in each bloom late in the afternoon.

## SUMMARY.

### CUTWORMS.

1. Plow sod land in the fall in preparing it for tobacco and keep down all vegetation during the winter and spring. This will starve the cutworms.

2. If sod land has not been treated as recommended above, use the poisoned bait four or five days before setting tobacco, or drop the bait about each hill directly after setting tobacco.

### FLEA-BEETLES.

3. Canvas seed beds tightly with strong whole canvas and thus prevent entry of the beetles.
4. Spray infested beds with arsenate of lead at the rate of 1 pound paste form (or ½ pound powdered form) to 12 gallons of water.
5. If flea-beetles are very numerous at setting time dip the *tops* of the plants in the arsenate of lead recommended in No. 4.
6. If flea-beetles continue to injure plants after setting, spray with arsenate of lead at the strength given above.

### TOBACCO HORNWORMS.

7. Nearly all the destructive late July and August "shower" of worms is the direct offspring of tobacco moths that have issued from hibernation during late July and early August.
8. Over 60 per cent of the hibernating generation of moths emerge from hibernation late in July and in August.
9. Fall plowing of land that was in tobacco during the year will destroy more than half of the hibernating generation and will thereby reduce proportionately the number of tobacco worms that will appear the next year late in July and in August.
10. Poison worms upon tobacco plants by dusting with Paris green.
11. Poison tobacco moths by placing a few drops of arsenide of cobalt (flystone) solution in "jimson" blooms.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *April 18, 1910.*

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 124.
L. O. HOWARD, Entomologist and Chief of Bureau.

# THE SAN JOSE SCALE AND ITS CONTROL.

BY

A. L. QUAINTANCE,

*In Charge of Deciduous Fruit Insect Investigations.*

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CIRCULAR No. 124. Issued August 12, 1910.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

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# THE SAN JOSE SCALE AND ITS CONTROL.[a]

By A. L. QUAINTANCE,
*In Charge of Deciduous Fruit Insect Investigations.*

## CHARACTER OF INJURY.

The San Jose or Chinese scale (*Aspidiotus perniciosus* Comstock) infests practically all portions of its host plants that are above ground—the trunk, limbs, and branches—and when abundant it may occur on the leaves and fruit. Injury results from the extraction, by the scale insects, of the juices of the plant. At first this merely checks growth, but as the insects increase in number the speedy killing of the branches and twigs follows, resulting finally in the death of the plants. In addition to the extraction, by the scales, of sap as food, the puncturing of the bark by the slender sucking mouth-parts results in a diseased and often pitted condition; the inner bark, or cambium, showing a reddish discoloration, as exposed in cutting with a knife, and the bark itself may crack, in stone fruits exuding drops or masses of gum. A reddening effect is also much in evidence as red rings around the scales on the bark, especially of the apple and pear, and on the fruits of these plants, though not characteristic of any one scale species.

On peach the scales have a tendency to infest to a greater extent the older limbs and branches than the newer growth, as the wood 1 year old. On apple and pear, the terminal twigs are quite generally infested, and many of the young may find their way to the fruit, settling principally in the calyx and stem cavities. Most varieties of fruit trees and plants infested from the nursery, in the absence of treatment, perhaps never reach fruiting condition.

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[a] An extended recent account of this insect will be found in Bulletin 62 of this Bureau, "The San Jose or Chinese Scale," by C. L. Marlatt, which may be obtained of the Superintendent of Documents, Government Printing Office, Washington, D. C., for 25 cents. Foreign applicants should send 4 cents additional to cover postage.

Peach trees will usually be killed in two or three seasons, while pear or apple trees will maintain a feeble existence much longer. This insect, on account of its great similarity to certain other species of scale insects, may not be positively determined except by specialists. The occurrence of diseased and dying branches showing severe scale infestation furnishes strong presumptive evidence of the presence of this pest, but specimens of infested twigs should be promptly submitted to a qualified person for examination.

The appearance of a 3-year-old peach tree, presumably infested from the nursery, is shown in figure 1. The principal limbs have

FIG. 1.—Appearance of 3-year-old peach tree badly injured by the San Jose scale (*Aspidiotus perniciosus*) the larger branches having been killed. (Original.)

already been killed, although new shoots have developed. A tree in this condition generally may be saved by the thorough pruning out of dead and badly injured wood and subsequently effecting the control of the scale by spraying.

The character of injury to an apple orchard, in which the trees were infested from outside sources four or five years earlier, is shown in figure 2. Although many of the limbs and branches are injured or killed, such trees may be saved and brought into vigorous condition by thorough pruning, and by insuring the control of the insect in the future.

## THE INSECT DESCRIBED.

The mature San Jose scale is small, grayish in color, circular in outline, somewhat convex, and with a nipplelike prominence in the center. The female scale is about 1 millimeter in diameter (about the size of a pin head); the male scale is much smaller and elongate. (See fig. 3.) The insect itself is beneath the so-called scale, this being simply a waxy covering secreted by the soft, helpless, yellow "louse" for its own protection. Where trees and plants are but slightly infested its presence is not readily detected by the casual observer, but in the case of severe infestation the bark of the tree and limbs

FIG. 2.—Appearance of an apple orchard badly infested by the San Jose scale; many of the limbs and branches killed. (Original.)

will present an ash-gray appearance, and on closer examination will be found thoroughly incrusted with the scales, which, when scraped with a knife, will produce a yellowish, oily fluid. When the scales are abundant on the tree the foliage also will be thoroughly infested, giving it a spotted and diseased appearance readily observable some feet away.

## NATURAL HISTORY AND HABITS.

The San Jose scale passes the winter in an immature condition fixed to the bark of the host plant, the small, dark-gray or blackish scales being just discernible with the unaided eye. In early spring,

with the ascent of the tree's sap, the growth of the scale begins, and early in April in the latitude of Washington the small, two-winged, active males issue from the male scales. After mating with

**Fig. 3.—Appearance of the San Jose scale, enlarged about 4 times; to the right, on peach; to the left, on apple. (Original.)**

the females the males die. The females continue to grow and in about a month begin the production of living young—minute, yellow, oval creatures, which by very close observation may be distinguished

without the aid of a hand lens, crawling here and there on the infested plants in an effort to find a suitable place for settlement. The young insect is active for some hours but soon settles, pushes its slender, threadlike beak into the plant, and begins to feed by sucking out the sap. After this there is no further movement from place to place, and the waxy covering, which often begins to develop before the insect has settled, soon covers it completely.

In about twelve days the insects molt and from this time on the male and female scales may be readily distinguished. Eight or ten days later the males change to pupæ, and in from twenty-four to twenty-six days from birth the adult males emerge and fecundate the females, which in turn reach maturity and begin the production of young in from thirty-three to forty days from birth. An individual female may give birth, on the seasonal average, to about 400 young, and as the life cycle of the female covers but a few weeks there may be several generations a year, the number varying according to latitude. The progeny from one parent during the season have been estimated at 1,608,040,200 females. It is thus easy to understand how the insect can so quickly destroy the plants infested and why prompt remedial measures are so necessary. With the approach of the cool weather of fall, breeding gradually ceases and the scales in all stages enter hibernation. Most of the older and also most of the younger individuals perish during the winter, the survivors being those about one-third or one-half grown, as stated.

## MEANS OF DISTRIBUTION.

The San Jose scale is distributed from one region to another principally on nursery stock, scions, or budding and grafting material. The danger of its dissemination in this way is fully realized, and laws are in force in the majority of States requiring the inspection of nurseries and the destruction of infested stock. Traffic in nursery produce is permissible only under the certificate of an official entomologist or inspector that the stock is free from the scale. In addition to the actual inspection of nurseries, further safeguard is furnished by the practice of most nurserymen (compulsory in some States) of fumigating the plants, before distribution, with hydrocyanic-acid gas.

After the insect once becomes established in a locality its spread is accomplished by various agencies. As explained under the natural history of the insect, it is capable of movement only during a short period after birth. During this crawling stage the insects are able to pass from tree to tree where the limbs are in contact. But it is by agencies independent of itself that it is principally distributed. Prominent among these factors are birds, which may alight upon infested trees, where the young insects may crawl upon

their feet and be subsequently deposited in other trees, sometimes at distances quite remote. It is probable that the young are blown by strong winds from tree to tree; and they are carried by insects, such as grasshoppers, ladybird beetles, ants, etc. The crawling "lice" may be transported considerable distances on the clothing of man, on vehicles, or on horses or other live stock which may be in orchards for any purpose.

The suggestion that the insect may be disseminated by means of scale-infested fruit (see fig. 4) has been frequently made, but it is the consensus of opinion among American entomologists that this danger, while undoubtedly existing, is negligible.

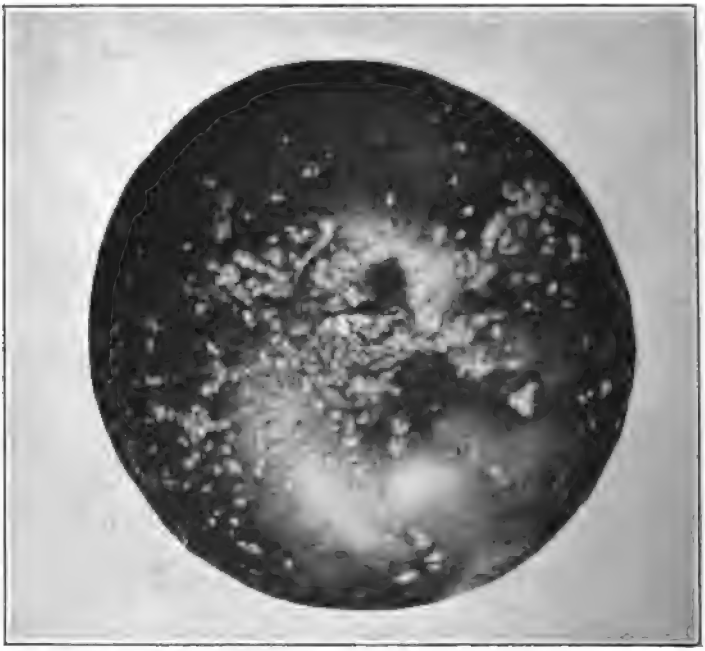

FIG. 4.—Baldwin apple badly infested with the San Jose scale. (Original.)

## FOOD PLANTS.

The San Jose scale infests practically all deciduous fruit trees, such as apple, pear, peach, plum, etc., and also many ornamental and shade trees. It is, however, seriously destructive to a much smaller number than that upon which it may actually maintain its existence. The following list of food plants, as compiled by Dr. W. E. Britton,[a] includes those that are commonly or badly infested:

[a] Report of the Connecticut Agricultural Experiment Station, 1902, Part II. 2d Report of the Entomologist, pp. 132–138.

*Acacia* sp. Lintner, Felt, N. Y.; Alwood, Va.
*Akebia* sp. Felt, N. Y.
*Akebia quinata* Decaisne. Alwood, Va.
*Amelanchier canadensis* Medic., and other species. Shad-bush, Juneberry. Britton, Koehler, Conn.; Alwood, Va.
*Citrus trifoliata* Linn. Scott, Ga.; Alwood, Va.; Gossard, Fla.
*Cornus alba* Linn. var. *sibirica* Lodd. Britton, Conn.
*Cornus baileyi* Coult. & Evans. Gould (in N. Y.)..
*Cornus sanguinea* Linn. Britton, Conn.
*Cotoneaster* sp.? Britton, Conn.; Lintner, Felt, N. Y.; Card, R. I.
*Cotoneaster vulgaris* Lindl. Alwood, Va.
*Cratægus* sp. Hawthorn. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
*Cratægus cordata* Soland. Koehler, Conn.
*Cratægus oxyacantha* Linn. English hawthorn. Britton, Koehler, Conn.
*Cratægus coccinea* Linn. Koehler, Conn.
*Cratægus crus-galli* Linn. Koehler, Conn.
*Cydonia vulgaris* Pers. Common quince. Britton, Conn.; Lintner, N. Y.; Alwood, Va.
*Cydonia japonica* Pers. Japanese or flowering quince. Britton, Koehler, Conn.; Lintner, N. Y.; Alwood, Va.; Johnson, Md.
*Fagus sylvatica* Linn. var. *purpurea* Ait. European purple-leaved beech. Smith, N.J.
*Juglans sieboldiana* Maxim. Japanese walnut. Britton, Conn.; Alwood, Va.; Sherman, N. C.; Smith, N. J.
*Ligustrum vulgare* Linn. Common privet. Alwood, Va.
*Populus* sp. Poplar. Britton, Conn.; Smith, N. J.; Sanderson, Del.; Felt, N. Y.
*Populus deltoides* Marsh. Carolina poplar. Britton, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
*Populus nigra* Linn. var. *italica* Du Roi. Lombardy poplar. Britton, Koehler, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
*Prunus amygdalus* Stokes. Almond. Lintner, N. Y.; Alwood, Va.
*Prunus armeniaca* Linn. Apricot. Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
*Prunus avium* Linn. Sweet cherry. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.; Cockerell, N. Mex.
*Prunus pumila* Linn. Koehler, Conn.
*Prunus pumila* var. *besseyi* Waugh. Sand cherry. Alwood, Va.
*Prunus cerasifera* Ehrh. var. *atropurpurea* Dipp. (*P. pissardi*). Purple-leaved plum. Britton, Conn.; Felt, N. Y.
*Prunus domestica* Linn. European plum. Britton, Conn.; Alwood, Va.
*Prunus hortulana* Bailey. Wild goose plum. Alwood, Va.
*Prunus japonica* Thunb. Flowering almond. Britton, Conn.; Felt, N. Y.
*Prunus maritima* Waugh. Beach plum. Koehler, Britton, Conn.
*Prunus persica* Sieb. & Zucc. Peach. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
*Prunus triflora* Roxbg. Japanese plum. Britton, Koehler, Conn.; Alwood, Va.
*Prunus serotina* Ehrh. Koehler, Conn.
*Prunus virginiana* Linn. Chokecherry. Koehler, Conn.
*Ptelea trifoliata* Linn. Hop tree. Fernald, Mass.
*Pyrus communis* Linn. Pear. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
*Pyrus sinensis* Lindl. Sand pear, including Kieffer. Alwood, Va.
*Pyrus baccata* Linn. Koehler, Conn.
*Pyrus malus* Linn. Apple. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Doten, Nev.; Cockerell, N. Mex.

*Pyrus* sp. Crab apple. Britton, Conn.
*Ribes oxyacanthoides* Linn. Gooseberry. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Troop, Ind.
*Ribes aureum* Pursh. Missouri or flowering currant. Lintner, N. Y.
*Ribes rubrum* Linn. Currant. Britton, Conn.; Lintner, Felt, N. Y.
*Ribes nigrum* Linn. Black currant. Alwood, Va.
*Rosa* sp. Britton, Conn.; Lintner, N. Y.; Alwood, Va.; Cockerell, N. Mex.; Burgess, Ohio; Troop, Ind.; Gould, Md.; Scott, Ga.
*Rosa carolina* Linn. Koehler, Conn.
*Rosa lucida* Ehrh. Koehler, Conn.
*Rosa virginiana* Mill. Koehler, Conn.
*Rosa rugosa* Thunb. Britton, Koehler, Conn.
*Salix* sp. Willow. Britton, Conn.; Felt, N. Y.; Sanderson, Del.
*Salix lucida* Muhl. Koehler, Conn.
*Salix pentandra* Linn. Laurel-leaved willow. Lintner, N. Y.; Alwood, Va.
*Salix vitellina* Linn. Koehler, Conn.
*Salix babylonica* Linn. Weeping willow. Lintner, N. Y.; Alwood, Va.
*Salix humilis* Marsh. Koehler, Conn.
*Salix incana* Schrank. Koehler, Conn.
*Sorbus* sp. Mountain ash. Felt, N. Y.; Hunter, Kans.
*Sorbus americana* Marsh. American mountain ash. Britton, Koehler, Conn.; Alwood, Va.
*Sorbus aucuparia* Linn. European mountain ash. Britton, Koehler, Conn.
*Sorbus melanocarpa* C. Koch (*Aronia nigra* Koehne). Black chokeberry. Koehler, Conn.
*Symphoricarpos racemosus* Michx. Snowberry. Felt, N. Y.; Smith, N. J.
*Syringa vulgaris* Linn. Common lilac. Burgess, Ohio; commissioner of agriculture, N. Y.; Troop, Ind.; Alwood, Va.
*Syringa persica* Linn. Persian lilac. Britton, Conn.
*Tilia* sp. Basswood, linden. Britton, Conn.; Lintner, commissioner of agriculture, N. Y.
*Tilia americana* Linn. American linden or basswood. Britton, Conn.; Alwood, Va.
*Toxylon pomiferum* Raf. Osage orange. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
*Ulmus* sp. Elm. Lintner, N. Y.; Webster, Ohio; Troop, Ind.
*Ulmus americana* Linn. American elm. Britton, Koehler, Conn.; Alwood, Va.
*Ulmus campestris* Smith. English or European elm. Britton, Conn.; Felt, N. Y.; Smith, N. J.

This list might be materially extended by recording those plants upon which the insect has at various times been taken but to which it is not especially injurious. The fears earlier expressed that the scale would eventually seriously infest our native forest growth have not been borne out, and in effect it requires treatment only on fruit trees and on ornamental trees and plants.

## NATURAL ENEMIES.

The San Jose scale is subject to attack by numerous predaceous and parasitic enemies, which render important service in its control. Practically, however, the combined influence of these several agencies is not sufficient to make up for the enormous reproductive

capacity of this insect. To preserve the plants from destruction, its control must be accomplished by artificial means, such as the use of sprays.

Among the more common predaceous insects which are observed feeding on the scale is the so-called pitiful ladybird (*Microweisea* [*Pentilia*] *misella* Lec.), illustrated in figure 5. This very small, convex, black beetle may generally be found by any observant person on scale-infested trees.

Another species that feeds very commonly on this and other scale insects is the twice-stabbed ladybird (*Chilocorus bivulnerus* Muls.). This is a very near relative and almost identical in appearance to

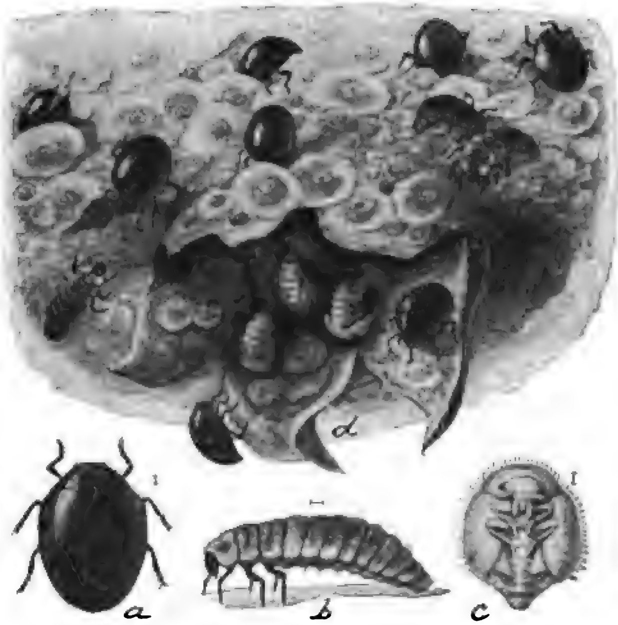


**Fig. 5.—The pitiful ladybird (*Microweisea* [*Pentilia*] *misella*): *a*, Beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ of Microweisea feeding on them, and pupæ of Microweisea attached within the calyx. All greatly enlarged. (From Howard and Marlatt.)**

the Asiatic ladybird (*Chilocorus similis* Rossi) (see fig. 6), which was introduced into this country from China through the activities of Mr. C. L. Marlatt, of the Bureau of Entomology, in the hope that its introduction would result in the control of this insect. The Asiatic ladybird, however, unfortunately proved to be subject to certain native parasites, while the necessity of spraying for the scale destroyed its food supply to such an extent that it was unable to maintain its existence.

Included among the parasitic Hymenoptera are certain natural enemies of an entirely different kind—very minute, four-winged flies (see fig. 7), which deposit their eggs upon or in the scales,

the resulting grubs consuming the body substance of their host in the course of their growth. The abundance of these small parasites varies greatly with the locality and the time of year. Dr. L. O. Howard,[a] who has given much attention to the parasites of the San Jose and other scales, records for this species the following: *Aphelinus fuscipennis* How., *Aphelinus mytilaspidis* Le B., *Aspidiotiphagus citrinus* How., *Anaphes gracilis* How., *Physcus varicornis* How., *Prospalta aurantii* How., *Ablerus clisiocampæ* Ashm., and *Rhopoideus citrinus* How.

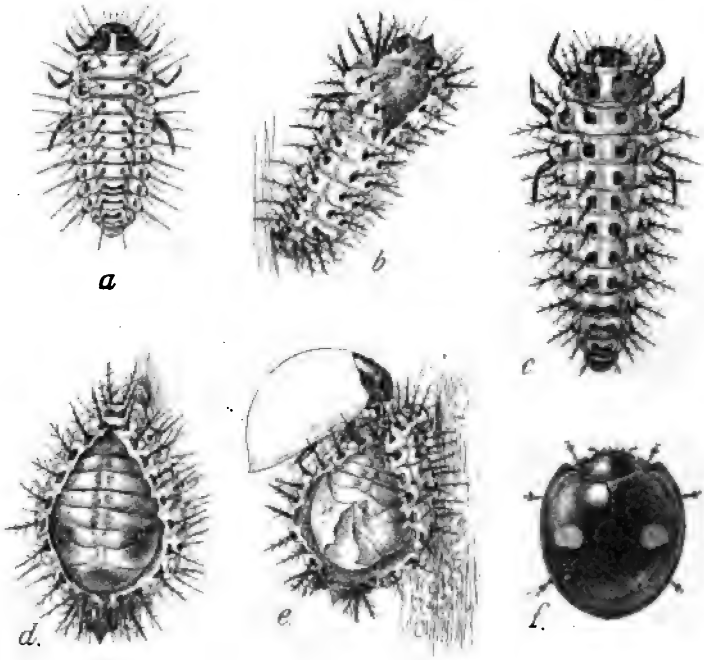


FIG. 6.—The Asiatic ladybird (*Chilocorus similis*), almost identical with the twice-stabbed ladybird (*C. bivulnerus*), predatory on the San Jose scale: *a*, Second-stage larva; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult. All enlarged to the same scale. (From Marlatt.)

Parasitism by these insects is indicated by a small round hole in the scale covering of the insect, through which the adult parasite has made its escape. Any orchardist, however, may satisfy himself as to the presence of these little friends by inclosing in a glass vial a badly infested twig, for in the course of a few days the minute flies, if present, will begin to emerge.

Considerable attention has been given to the subject of fungous diseases of the San Jose scale, and numerous attempts conducted in a thoroughly scientific manner, notably by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, have been made to

[a] Bul. 62, Bureau of Entomology, U. S. Dept. of Agriculture, pp. 58–62, 1906.

utilize one of these parasitic plants in the control of the insect. The fungus in question, *Sphærostilbe coccophila,* is cosmopolitan in its distribution, infesting many diaspine scale insects, and in Florida and the territory adjacent to the Gulf it is quite generally present on scales in orchards and on shade and forest trees. Its abundance and effectiveness, however, depend upon certain weather conditions, and therefore vary considerably.

## CONTROL MEASURES.

As has been already stated, the San Jose scale, in the absence of proper treatment, will quickly bring about the death of most plants of economic importance. Its discovery, therefore, whether in orchards or on prized fruit trees and other plants in the yard, should call for prompt steps to effect its control. It has been amply demonstrated that the scale may be very successfully controlled, and

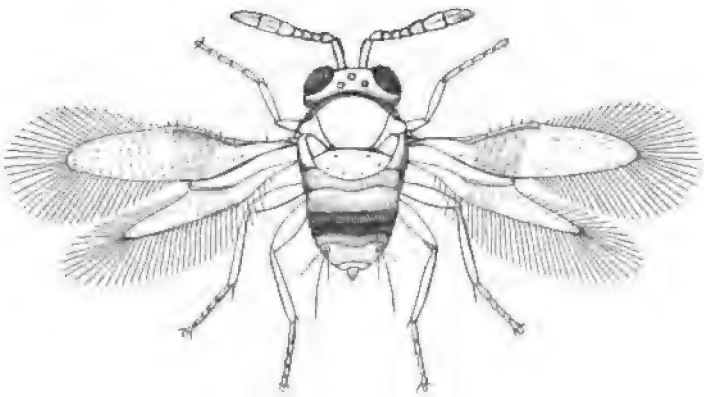

FIG. 7.—*Aspidiotiphagus citrinus*, a hymenopterous parasite of the San Jose scale. Greatly enlarged. (From Howard.)

practically its presence merely requires one thorough treatment during the dormant period each year. On account of the general distribution of the pest, extermination is in most cases out of the question.

Where plants are thoroughly incrusted, with consequent death of branches and stunting of growth, it will generally be advisable to dig out the trees at once and replace with new ones. Previous to spraying infested trees, the dead and weakened wood should be pruned out, which will simplify the work of spraying and will hasten the formation of new sound wood.

There are several scale washes which may be employed in the control of the insect, and the one should be selected which can be most conveniently used and which is economical under the circumstances. Thus, for spraying on a large scale the orchardist could properly afford expenditures for the construction of cooking outfits

for lime-sulphur wash which would not be justified where but a few plants were involved. For a few plants it would be better to use some one of the prepared washes put up by manufacturers. In fact, many large orchardists prefer to use sprays of this class in preference to making the washes at home. The possibility of injury to the trees from the sprays must also be borne in mind. All treatments, if possible, should be made during the dormant period (this is to say, in late fall or early spring, or even during the winter in mild climates), since at this time washes may be applied at much greater strengths than when the trees are in foliage. The aim is to use the wash about as strong as the tree will stand, thereby securing the maximum killing effect upon the insects. Used in this way the washes of the petroleum or kerosene series are most likely to cause injury to the fruit buds and tender twigs, and the lime-sulphur washes least likely to do so. Whale-oil-soap sprays as recommended for dormant trees are comparatively safe, though reports are at hand of injury to fruit buds, especially from fall applications. Stone fruits, such as peach, plum, etc., are more susceptible to injury from sprays than apple and pear, and on the former the lime-sulphur sprays should always be used. Petroleum and miscible oils are more frequently used on apple and pear, and owing to their spreading and penetrating qualities are perhaps more effective in destroying the scales on the terminal twigs, which are infested to a greater extent in the case of these fruits. The several sprays in use may be considered under the following headings: (1) Lime-sulphur wash series; (2) petroleum oil series (including miscible oils), and (3) soap wash series.

### LIME-SULPHUR WASHES.

For many years the cooked lime-sulphur wash has been the main reliance in the control of the scale. It is made according to the following formula:

| | |
|---|---|
| Stone lime.....pounds.. | 20 |
| Sulphur (flour or flowers).....do.... | 15 |
| Water to make.....gallons.. | 50 |

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no

stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray pump or tank. The wash may be cooked in large kettles or, preferably, by steam in barrels or tanks.

This wash has proved entirely effective in controlling the insect on all plants, so far as preserving their life is concerned, and has been especially satisfactory for stone fruits. For the apple, however, it has not in all cases been so satisfactory, as difficulty is experienced, especially in the case of large trees, in making the application sufficiently thorough to kill all the scales. The spotting of the fruit by the progeny of those that escape renders it unsightly for market purposes, though its intrinsic value is but little reduced. The presence of the scale is furthermore very objectionable for the reason that certain foreign governments and certain States in this country rigidly quarantine against fruits showing the presence of this insect. Considerable loss on fruit exported thus results to orchardists and dealers.[a]

Some apple growers rely principally upon the oil sprays, or use them at least every other year, alternating with the lime-sulphur wash, and in this way keep the scale well in check.

### CONCENTRATED LIME-SULPHUR SOLUTIONS.

The inconvenience experienced in preparing the lime-sulphur wash by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Certain manufacturers have therefore put on the market concentrated solutions of lime-sulphur wash, which have only to be diluted with water for use. These commercial washes have proved to be about as effective in controlling the scale as the well-cooked lime-sulphur wash, and, although somewhat more expensive, have been adopted by many commercial orchardists in preference to the home-prepared spray. They are especially useful for the smaller orchardist, whose interests do not warrant the construction of a cooking plant. In other ways, too, they possess advantages; for instance, those using the commercial washes may have always on hand a stock solution, so that the spray may be quickly prepared and advantage taken of favorable weather conditions.

### HOMEMADE CONCENTRATED LIME-SULPHUR SOLUTIONS.

The question of the preparation at home of concentrated lime-sulphur solutions which will not crystallize upon cooling, thus duplicating essentially the commercial product, has been the subject of inves-

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[a] Experiments made by the Bureau of Entomology indicate the practicability of successfully fumigating scale-infested apples intended for export or other trade. (See Bul. 84, Bur. Ent., U. S. Dept. Agr., 1909.)

tigation by several entomologists, notably by Cordley in Oregon, Stewart [a] in Pennsylvania, and Parrott [b] in New York State. These gentlemen have demonstrated that it is practicable for orchardists to prepare concentrated stock solutions of lime-sulphur wash for immediate or later use. Several orchardists have already adopted this plan, and it will doubtless come into more general use in the future. The details of the preparation of concentrated lime-sulphur solutions can not properly be given in the scope of this circular, but those interested should secure, if possible, copies of reports on the work from the directors of the respective experiment stations.

### SELF-BOILED LIME-SULPHUR WASH.

In the earlier experiments with the lime-sulphur wash in the East many efforts were made to avoid the necessity of cooking the wash by utilizing, to dissolve the sulphur, the heat generated by the slaking of the lime, or supplementing this by the addition of a quantity of caustic soda or potash. This preparation, formerly designated as self-boiled lime-sulphur wash, has now largely, if not entirely, fallen into disuse, and the spray under consideration is essentially a different preparation and was developed primarily as a fungicide.

Experiments made by the Bureau of Entomology in the vicinity of Washington in 1908, however, have shown that this self-boiled wash, by destroying the young insects and interfering with their establishment, is an excellent summer treatment for the San Jose scale. It is also effective in destroying aphides and, in addition, as stated, will prevent numerous fungous diseases, as established by Prof. W. M. Scott, of the Bureau of Plant Industry. Its use is especially recommended for scale-infested fruit trees which should receive applications of a fungicide and which may be more or less affected with aphides. By the addition of arsenate of lead, at the rate of 2 pounds to 50 gallons of spray, the wash also becomes effective against biting insects, such as the codling moth and plum curculio, and this furnishes as nearly an all-around spray as anything at present known.

It is possible that the commercial concentrated lime-sulphur wash, previously referred to, used at the rate of 1½ gallons to 50 gallons of water, would destroy many of the young San Jose scales. It has been shown to be an excellent fungicide, and at this strength not injurious to the foliage. Arsenate of lead may also be added, as in the case of the self-boiled wash.

In using the self-boiled lime-sulphur wash as a scale treatment, however, especial pains should be taken to coat the limbs and branches

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[a] Bul. 99, Pa. State Coll. Agr. Exp. Sta. (State College, Pa.), 1910.

[b] Bul. 320, N. Y. Agr. Exp. Sta. (Geneva, N. Y.), 1909.

of the infested trees, and, on account of the presence of the leaves, careful work will be necessary to accomplish this. This wash is made as follows:

| | | |
|---|---|---|
| Stone lime | pounds.. | 8 |
| Sulphur (flour or flowers) | do.... | 8 |
| Water to make | gallons.. | 50 |

The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

The stage at which cold water should be poured on to stop the cooking varies with different grades of lime. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot fifteen or twenty minutes after the slaking is completed the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely-divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through a strainer. The mixture can be prepared in larger quantities if desirable, say enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons), and then diluted to 200 gallons.

The first application should be given when the young scale insects are beginning to crawl, which time will vary according to locality. In the neighborhood of Washington this will be about the middle of May, earlier in the South, and later in the North. This one treatment, if thoroughly applied, will do much to check the increase of the insect and to protect the trees from serious damage until the more thorough winter application can be made. A subsequent application should be given, if practicable, in the course of five or six weeks in order to destroy the young scales of the second generation.

## PETROLEUM-OIL SERIES.

Under the heading "Petroleum-oil series" are to be included kerosene and crude petroleum, either pure or in emulsion, and the so-called miscible oils.

*Pure kerosene treatment.*—Pure kerosene has been more or less recommended for spraying trees badly infested with the scale, but it has never been very generally employed. There is no question of the efficiency of such an application in the destruction of the insects, but the great danger of injury to the plants precludes its general application. Treatments of pure kerosene should be made only during bright days and should be applied through a nozzle with a very fine aperture. Only the minimum amount of kerosene necessary to cover the trees should be given, and care is necessary that the liquid does not puddle around the roots of the trees.

*Pure crude petroleum treatment.*—Pure crude petroleum is used in identically the same manner as pure kerosene, and the same cautions as to its use should be remembered. The crude oil employed in the East is known as "insecticide oil" and has a specific gravity of 43 to 45 degrees on the Beaumé scale.

*Kerosene emulsion (stock solution 66 per cent oil).*—Kerosene emulsion is made after the following formula:

| | | |
|---|---|---|
| Kerosene (coal oil, lamp oil) | gallons.. | 2 |
| Whale-oil soap or laundry soap (or 1 quart of soft soap) | pound.. | ½ |
| Water | gallon.. | 1 |

Dissolve the soap in boiling water; then remove vessel from the fire. Immediately add the kerosene, and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before using. In order to make a 10 per cent spray (the strength for trees in foliage), add to each 1 gallon of the stock solution about 5⅔ gallons of water. For 20 and 25 per cent emulsions (for use on dormant trees and plants), use, respectively, about 2⅓ gallons and 1⅔ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will be required, as the kerosene will combine readily with the naphtha soap in water when thoroughly agitated. Of naphtha soap, however, double the quantity given in the above formula will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard" this should first be broken with a little caustic potash or soda, such as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene; or rain water may be employed.

*Crude petroleum emulsion.*—Crude petroleum emulsion may be prepared in identically the same way as described for kerosene emulsion, substituting crude petroleum for kerosene. The same dilutions for winter and summer spraying should be made as prescribed for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

*Miscible oils.*—Under the heading "Miscible oils" are to be designated several proprietary preparations which are essentially petroleum oils with the addition of a vegetable oil and an alkali, to secure ready saponification with water. These come in concentrated solutions and the spray is prepared by adding a specified amount of water. In point of convenience they leave little to be desired. Miscible oils are coming into increased use in place of kerosene or crude petroleum, either pure or in emulsions, and have a distinct usefulness as winter sprays about the same as have the concentrated lime-sulphur solutions. As has been indicated, the petroleum oils are at times the cause of injury to twigs and fruit buds, and it is a question of judgment whether, under conditions of severe scale infestation, the petroleum oils or the sulphur solutions should be used. The petroleum oils, on the whole, are more effective and the danger of injury from them is less to pome than to stone fruits.

The practicability of making miscible oils at home has been investigated by Prof. C. L. Penny,[a] and he has shown it to be entirely feasible, as detailed in the publications cited below.

### SOAP WASHES.

Practically the only soap wash which has come into extended use against the San Jose scale is that made from whale-oil soap. This is used mostly on dormant trees, the soap being employed at the rate of 2 pounds to the gallon of water. A potash whale-oil soap is preferable and should contain not more than 30 per cent of water. Soda soaps, while perhaps cheaper, will be likely to solidify on cooling when used at the strength above indicated, and are hence forced through the spray-pump nozzle with difficulty. For spraying trees in foliage the soap should be used at the rate of 1 pound to 3 or 4 gallons of water, or somewhat weaker.

### SPRAYING APPARATUS.

The washes as above described are applied by means of some form of spray pump, the size and character depending upon the size of the plants to be treated. For small plants, such as ornamentals, hedges, etc., a bucket pump (fig. 8) or knapsack pump (fig. 9) will be satisfactory. The barrel form of pump, however (fig. 10), will permit of more thorough work and will be suitable for orchards of some size.

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[a] Bul. 75, Del. Coll. Agr. Exp. Sta. (1906).
Bul. 85, Pa. State Coll. Agr. Exp. Sta. (1908). State College, Pa.

It may be placed in a wagon or cart or mounted on a sled. For large commercial orchards the hand-power tank or gasoline outfits are better.

It is quite practicable, however, in case but two or three trees in a yard are to be treated, to apply the wash to the limbs and branches

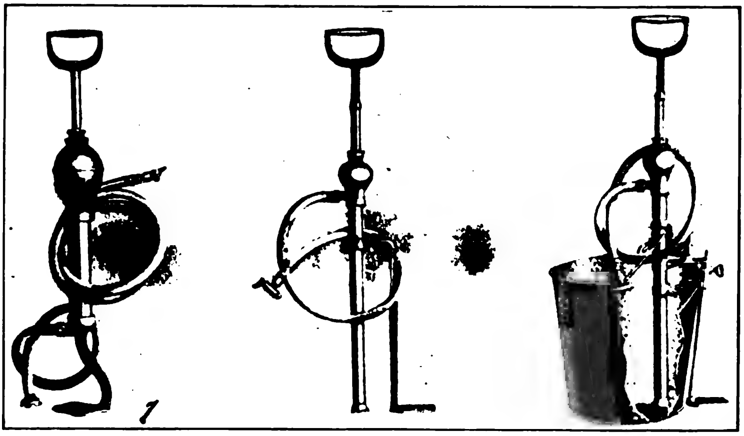



FIG. 8.—Bucket spray pump suitable for use in yards. (Author's illustration.)



FIG. 9.—Knapsack sprayer suitable for spraying low-growing plants. (Author's illustration.)

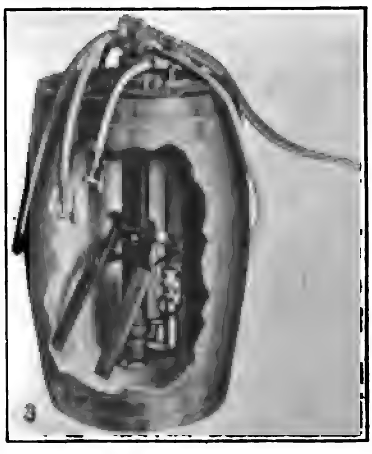



FIG. 10.—A barrel sprayer, suitable for orchard or similar large-scale work. (Author's illustration.)

by means of old cloths or brushes. Whale-oil soap is excellent for this purpose. Severe pruning of the trees is usually desirable in such cases.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *May 27, 1910.*

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 125.

L. O. HOWARD, Entomologist and Chief of Bureau.

# INSECTS WHICH KILL FOREST TREES:

## CHARACTER AND EXTENT OF THEIR DEPREDATIONS AND METHODS OF CONTROL.

BY

A. D. HOPKINS,

*In Charge of Forest Insect Investigations.*

64136°—Cir. 125—10

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

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# INSECTS WHICH KILL FOREST TREES: CHARACTER AND EXTENT OF THEIR DEPREDATIONS AND METHODS OF CONTROL.[a]

By A. D. HOPKINS,

*In Charge of Forest Insect Investigations.*

It has been conclusively demonstrated that certain species of insects are the direct or primary cause of the death of forest trees of all ages, and that from time to time they multiply to such an alarming extent that their depredations assume the character of a destructive invasion, which results in the death of a large percentage of the best timber over thousands of square miles.

There are many species of barkbeetles which prefer to attack matured and healthy trees, and there are many examples of whole forests of century-old trees that have perished from the girdling effect of the mines of the beetles, which are extended in all directions through the inner living bark on the main trunks of the trees. Indeed, we find among these bark-boring beetles the most destructive insect enemies of North American forests. Some notable examples of the depredations of these barkbeetles are given below.

*The southern pine beetle.*—In 1890–1892 a destructive invasion of the southern pine beetle extended from the western border of West Virginia through Maryland and Virginia into the District of Columbia, northward into southern Pennsylvania, and southward into North Carolina. In this area, aggregating over 75,000 square miles, a very large percentage of the mature and small trees of the various species of pine and spruce was killed by this beetle. In many places in West Virginia and Virginia nearly all the pine trees of all sizes on thousands of acres were killed, while shade and ornamental trees within the same area suffered the same as those in the forest. Since 1902

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, 1909.

this barkbeetle has been more or less active in the Southern States from Virginia to Texas, and in some localities and during certain years it has killed a large amount of timber. Records of extensive destruction of timber in the Southern States are found dating back to the early part of the nineteenth century. This species may be considered one of the most dangerous insect enemies of southeastern conifers and, therefore, a constant menace to the pine forests of the Southern States.

*The eastern spruce beetle.*—During the period between 1818 and 1900 there were several outbreaks of the eastern spruce beetle in the spruce forests of New York, New England, and southeastern Canada. This species caused the death of a very large percentage of the mature spruce over an area of thousands of square miles. In the aggregate many billions of feet of the best timber were destroyed. The larger areas of this dead timber furnished fuel for devastating forest fires, with the result that in most cases there was a total loss.

*The Engelmann spruce beetle.*—The Engelmann spruce beetle, with habits similar to the eastern spruce beetle, has from time to time during the past fifty years caused widespread devastations in the Rocky Mountain region to forests of Engelmann spruce, in some sections killing from 75 to 90 per cent of the timber of merchantable size.

*The Black Hills beetle.*—One of the most striking examples of the destructive powers of an insect enemy of forest trees is found in the Black Hills National Forest of South Dakota, where during the past ten years a large percentage of the merchantable timber of the entire forest has been killed by the Black Hills beetle. It is estimated that more than a billion feet of timber have been destroyed in this forest as the direct result of the work of this beetle. This destructive enemy of the western pine is distributed throughout the forests of the middle and southern Rocky Mountains region, where, within recent years, it has been found that in areas of greater or less extent from 10 to 80 per cent of the trees have been killed by it.

*The mountain pine beetle and the western pine beetle.*—The sugar pine, silver pine, western yellow pine, and lodgepole pine of the region north of Colorado and Utah, westward to the Cascades, and southward through the Sierra Nevadas are attacked by the mountain pine beetle and the western pine beetle, and, as a direct consequence, billions of feet of the timber have died. In one locality in northeastern Oregon it is estimated that 90 to 95 per cent of the timber in a dense stand of lodgepole pine covering an area of 100,000 acres has been killed within the past three years by the mountain pine beetle. Through many sections of the sugar-pine districts of Oregon and California, as the result of attacks by this same destructive barkbeetle a considerable percentage of the largest and best trees is dead.

*The Douglas fir beetle.*—The Douglas fir throughout the region of the Rocky Mountains from southern New Mexico to British Columbia has suffered severely from the ravages of the Douglas fir beetle, with the result that a large percentage of dead timber is found, much of which will be a total loss.

Three other species of beetles, having destructive habits similar to those above mentioned, depredate on the pines of New Mexico and Arizona, and still another has contributed greatly to the destruction of the larch throughout the northeastern United States and southeastern Canada.

*The hickory barkbeetle.*—Within the past ten years the hickory barkbeetle has caused the destruction of an enormous amount of hickory timber throughout the northern tier of States from Wisconsin to Vermont and southward through the eastern Atlantic States and into the Southern States as far as central Georgia.

*The larch worm.*—There are also many examples of widespread depredations chargeable to insects which defoliate the trees, thus contributing to their death. Notable among these are the depredations by the larch worm, which, during several extensive outbreaks since 1880, has killed from 50 to 100 per cent of the mature larch over vast areas in the northeastern United States and southeastern Canada. It is evident that the amount of merchantable-sized timber that has died as the result of defoliation by this insect will aggregate many billions of feet.

## CONTROL OF BARKBEETLES WHICH KILL TREES.

The barkbeetles which kill trees attack the bark on the trunk and destroy the life of the tree by extending their burrows or galleries in all directions through the inner living bark. The broods of young grubs or larvæ develop within the inner bark, on which they feed. Those of some species develop to the adult stage within the inner bark and are exposed when the bark is removed, while those of other species transform to the adults in the outer corky bark and the larvæ are not exposed when the bark is removed. Some species have two or more generations in a season or annually, while others have but one, and in a few species it requires two years for a single generation to develop.

The barkbeetles of the genus Dendroctonus represent the most destructive enemies of the principal coniferous tree species of American forests, and at the same time are among the easiest of control. The general requisites for success are embodied in the following rules:

(*a*) Give prompt attention to the first evidence of a destructive outbreak, as indicated by an abnormal percentage of yellow or red topped dying trees, and especially when such trees occur in groups of ten or more or cover large areas; (*b*) secure authentic determination

of the particular species of insect responsible for the trouble; and (*c*) take prompt action toward its control according to specific expert advice, published or otherwise, on the best method for the destruction of the necessary 75 per cent or more of the insects in the infested trees.

Some of the methods to be adopted to meet the requirements of various local conditions are as follows:

(1) Utilize the infested timber and burn the slabs during the period in which the broods of the destructive beetles are in the immature stages or before the developed broods emerge from the bark; or

(2) Fell the infested trees and remove the bark from the main trunk and burn the bark if necessary;[a] or

(3) Remove the infested bark from the standing timber and burn the bark when necessary;[a] or

(4) Immerse the unbarked logs in ponds, lakes, or streams, where the bark will remain soaked long enough to kill the insects; or

(5) Remove the unbarked logs or products to a locality where there are no trees liable to attack within a radius of 20 miles or more.

### Maintaining Control of Barkbeetles.

Future trouble of a serious nature from barkbeetles which kill trees can be prevented within a given forest or area of greater or less extent if an insect-control policy is adopted in connection with, or independent of, a fire-control policy by which groups of dying trees will receive similar prompt attention as that required for the prevention or control of forest fires.

*In state and national forests.*—In all forest reserves in which there is an organized force of rangers and fire wardens or patrols each officer should be furnished with instructions for the location of beetle-infested trees, and with equipment and directions for taking the necessary action whenever the conditions demand or warrant it.

*In private forests.*—Private forests should receive the same attention as public forests, but this is often far more difficult on account of intervening forests where the owners either can not or will not give the matter the required attention. While it may be advisable to have some laws to govern the treatment of timber infested with a dangerous pest when the owner refuses to take any action, such a law should apply only to the more extreme cases or as a last resort on authoritative advice. It is probable that in most cases legislation will not be necessary, and more ultimate good will result without than with strict laws, especially when it can be made clear to the

[a] If the broods develop to adults in the outer bark, it must be burned; if they develop in the inner bark and are exposed when the bark is removed, burning is not necessary. As a rule the burning of the tops to destroy the insects is not necessary.

owner that his personal interests demand that he take the proper action and that, when necessary, his neighbors will render assistance, as is done in the case of a forest fire.

*Inaccessible areas.*—There are yet large inaccessible areas in the East and West where it is not practicable or possible at present to control the depredations by these beetles and which must therefore be left to the same natural adjustment that has been going on in all forests from their beginning. While under such natural control much of the older matured timber will be lost it will usually be replaced by young growth, either of the same species of trees or of a different species, so that under normal conditions the forest will be perpetuated; but under exceptional conditions and combinations of detrimental influences, such as secondary insect enemies, fire, and drought, extensive areas may be completely denuded, never to be reforested under natural conditions. Therefore it will evidently not be very long before it will pay to adopt insect-control policies even in the areas that are inaccessible for profitable lumbering.

## Examples of Successful Control of Barkbeetles.

The practicability of the advice based on the results of recent entomological investigations is demonstrated by a number of examples of successful control of depredations by destructive barkbeetles.

### CONTROL OF THE EASTERN SPRUCE BEETLE.

The control of an alarming outbreak of the eastern spruce beetle in northeastern Maine in 1900 and 1901 was effected by the concentration of regular logging operations into the areas of infested timber and placing the logs in lakes and streams and driving them to the mills on the Androscoggin River. Thus, with little or no additional expense, there was a saving to one firm, according to its estimates, of more than $100,000.

### CONTROL OF THE HICKORY BARKBEETLE.

The complete control of the hickory barkbeetle, which threatened the total destruction of the hickory trees on Belle Isle Park, at Detroit, Mich., in 1903, was effected by felling and removing the infested trees and converting them into merchantable products, all without cost to the park commission.

### CONTROL OF THE BLACK HILLS BEETLE.

An extensive outbreak of the Black Hills beetle in the vicinity of Colorado Springs, Colo., in 1905–6, which was threatening the living pine timber of the entire section, was brought under control through the efforts of the private owners of forests and those of forest officials in the adjoining National Forests. It was accomplished by

cutting and barking about 1,000 beetle-infested and beetle-killed pine trees. The cost of the operations was largely, if not entirely, covered by the utilized felled timber, although there was considerable unnecessary expense involved through the felling and barking of trees from which the beetles had emerged and from the unnecessary burning of the bark and tops.

The successful control of another serious outbreak of this beetle, in 1906, on an extensive private estate in southern Colorado, was effected through the efforts of the owners, who had some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. These operations were so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the value of utilizable timber was probably more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented.

The practicability of controlling this most destructive enemy of the pine timber of the central Rocky Mountain region, not only without ultimate cost but at a profit on the operations, was demonstrated on a large private estate and the adjoining Pike National Forest in north-central Colorado. An examination of the timber on this estate in the spring of 1907, by a ranger detailed from the Forest Service to work under instructions from the Bureau of Entomology, showed that the depredations by the beetle had been going on for the past ten years or more and had resulted in the death of the choicest timber to the extent of more than 800,000 board feet. About 65,000 board feet of timber was found to be infested by the beetle at the time of the examination. The owner was notified by the Bureau of Entomology of the dangerous character of the infestation and the required action for its control was recommended, but no action was taken. Another examination of the property was made in the fall of 1907, when it was found that the new infestation resulting from swarms of beetles that had been allowed to emerge from the old infested trees involved nearly four times as much timber, or 240,000 board feet. This alarming increase led to the prompt adoption of the recommendations by the owner and the Forest Service, and by May of the following spring (1908) the small number of trees on the National Forest was cut and barked, to kill the insects in the inner bark, and the 1,000 trees on the private estate were felled, the logs converted into lumber, and the slabs burned, which accomplished the desired purpose of destroying the broods of the beetle. The owner realized a sufficient revenue from the timber thus involved to cover all expenses and leave a net profit of over $1,200. Examination of the area in the fall of 1908 showed that this prompt and properly conducted effort to con-

trol the beetle was a complete success. Thus the average death rate of some 100,000 feet of timber annually during the past ten or more years was reduced to a minimum, at a net profit on the cost of doing it.

In addition to infested trees disposed of by the Forest Service in timber sales, 165 infested trees in one section of the Las Animas National Forest were cut and barked in May and June, 1908, at a direct cost of $177.50, and at the same time a considerable amount of infested timber was disposed of by sale in the Wet Mountains section of the San Isabel National Forest. This had a decided effect in checking the ravages of the beetle in both of these forests and it was followed up in the latter forest the next spring (1909) by the proper disposal of over 1,000 infested trees by free use, ranger labor, and direct expenditure of funds appropriated by the Forest Service. According to the forest supervisor's report, 80.7 per cent of the infested trees were treated, ranging from 70 per cent to 92.5 per cent on the five units of infestation; 795 trees were treated (535 barked, and 260 felled and bark scorched) at the expense of the Forest Service, including salary and expenses of rangers. The cost per tree was about 60 cents for felling and barking, and ranged from 52 to 78 cents for felling and scorching the bark on the infested trunks. The average cost per tree was 68.2 cents. Six hundred and twenty-six trees were treated by temporary labor, at an average cost of 61 cents per tree under contract at $1.50 to $2 per hundred feet in length of trunk peeled. The same rate was allowed for scorching the infested bark instead of removing it. Two hundred and seventy-five trees were treated under administrative use without cost to the Forest Service.

In September, 1909, a very thorough examination was made of the timber in and adjacent to the areas involved in the control operations, and it was found that the thorough, prompt, and proper manner in which the instructions of the Bureau of Entomology were carried out in this case resulted in bringing the beetle under complete control. Only 7 trees had been successfully attacked by the beetles which had emerged from some 400 infested trees which were not cut during the previous control operations. Over 100 trees were found that had been attacked by the beetles, but, owing to the limited number of the latter, the trees were able to resist them and recover.

It is now evident that the control operations carried on in southern Colorado during the past three years, on the Trinchera estate near Fort Garland in 1906, in the Las Animas National Forest and Wet Mountains section of the San Isabel National Forest in 1908, and the more extensive work in the latter area in 1909, had a far-reaching effect in bringing the Black Hills beetle under control within the forested areas of southern Colorado, and that the loss of timber

from this source, amounting to an average of some 300,000 board feet annually, has been reduced to a minimum.

These results mark the most important events in the control of forest insects in this country and serve as striking demonstrations of what can be accomplished when cooperative efforts are directed along the proper lines and based on the results of scientific investigation. The attainment of these results was due to three important factors: First, a knowledge of the insects on which the recommendations by the Bureau of Entomology were based; second, a knowledge of local conditions and requirements and of the habits of the insects in relation to newly infested trees, which enabled a forest ranger to locate the infested trees and give instructions to the forest officials in regard to such locations and the essential details in the recommendations; third, a prompt and proper practical application by the Forest Service of the recommendations according to improved forestry methods to meet the requirements of a forestry problem.

Ten years ago it would have been absolutely impossible to have accomplished this result, owing to the utter lack of knowledge of the first two of these features, and at the present time it would have been impossible without the assistance of the Forest Service.

### CONTROL OF THE MOUNTAIN PINE BEETLE.

A very threatening outbreak of the mountain pine beetle was located, in 1909, in the Snowy Mountains section of Montana, adjacent to and within the Jefferson National Forest, involving, at the time, more than 1,500 infested and dying trees. The infestation included timber on the National Forest, public domain, state lands, and private lands, thus involving a complication of federal, state, and private interests with which to deal in securing the required action. The case was so successfully managed that an agent of the Bureau, Mr. Josef Brunner, was placed in complete charge to carry out the recommendations and instructions of this Bureau, and, through the aid of the Forest Service, state officials, and private owners, 1,355 infested trees were cut and barked to kill the broods of beetles. The cutting was started about June 15, 1909, and was completed about July 24 of the same year. Four hundred and twenty-two trees were cut at private expense, 783 at the expense of the Forest Service, and the remainder by local owners. The average cost for felling and removing the bark from the infested portion of the trunk was 30 cents per tree.

Early in December, 1909, a careful examination was made of the area for evidence of new infestation. It was found that, while some 56 trees had been attacked by the mountain pine beetle, the broods were being destroyed by woodpeckers and other natural enemies, and that, therefore, the efforts to control the beetle depredations were a complete success.

The examples of practical control given above have demonstrated at least two important facts: One, that extensive outbreaks by two of the most destructive bark-beetle enemies of the pine timber of the Rocky Mountain forests can be controlled at moderate expense when the timber is not accessible for utilization, or at a profit whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details of the recommendations and expert advice, based on the results of scientific research, can be successfully applied by a manager of a private forest or by the rangers of national and state forests. Furthermore, these results indicate quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and essentially the same recommendations submitted as in the cases mentioned. Failure to do so was through the lack of public appreciation of the importance of the problem at the time and the lack of sufficient authority and funds later. Therefore the outbreak was allowed to extend beyond practical control, and in consequence a large percentage of the timber of the entire National Forest has been killed. There were then no forcible examples of the practical value of recommendations based on scientific research, and no other argument was effective in arousing public interest in the threatening character of the outbreak or confidence in the advice and methods of control. Now that the practicability of controlling the most destructive insect enemies of North American forests has been demonstrated, this should lead to a more general interest in the subject and confidence in the results of scientific research as a basis for success in practical application.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *October 7, 1910.*

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United States Department of Agriculture,
BUREAU OF ENTOMOLOGY.
L. O. HOWARD, Entomologist and Chief of Bureau.

# INSECT INJURIES TO THE WOOD OF LIVING TREES.[a]

By A. D. HOPKINS,
*In Charge of Forest Insect Investigations.*

It has been determined that insects of a certain class attack the wood and bark of living timber and that, while they do not contribute materially to the death of the trees or give much external evidence of their presence, they produce wounds in the bark and wormhole and pinhole defects in the wood which result in a depreciation in commercial value amounting to from 5 to 50 per cent. These defects in the wood are not detected until after the trees have been felled and the logs transported to the mill and converted into lumber. Thus to the actual damage to the lumber is added the expense of logging and manufacture of the defective, low-grade material, much of which must be discarded as worthless culls.

*The oak timber worm.*—One of the most destructive of the class of depredators just mentioned is the oak timber worm. It enters the wood of the trunks of living trees through wounds in the bark and at the base of broken or dead branches and extends its "pinhole" burrows in all directions through the solid heartwood. The losses occasioned by this insect in the hardwood forests of the eastern United States are enormous and usually affect the wood of the finest examples of old trees.

*The chestnut timber worm.*—The chestnut throughout its range is damaged in a like manner by the chestnut timber worm. Practically every tree of merchantable size is more or less affected, and a large percentage is so seriously damaged that the product is reduced to that of the lowest grade. It is estimated that the reduction in value of the average lumber product at any given time is not far from 30 per cent,

[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture. 1909.

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thus involving extensive waste and an increased drain on the forest to supply clear lumber. This insect also attacks the oaks, and especially the red oak, the older trees of which are often as seriously damaged as are the chestnut.

*Carpenter worms.*—The oaks, especially the white oak and the red oak, are seriously damaged by carpenter worms of the genus Prionoxystus. The holes made by these insects through the heartwood of the best part of the trunks are sometimes 1.5 inches in diameter one way by 0.75 inch the other, thus causing serious damage to the wood. These, with other large wood-boring beetle larvæ, sometimes infest the top part of the trunk and the larger branches of oak trees, where their continued work results first in the dead and so-called "staghorn" top and subsequently in broken, decayed, and worthless trunks.

*Ambrosia beetles.*—One of the commonest defects in white oak, rock oak, beech, whitewood or yellow poplar, elm, etc., is that known to the lumber trade as "grease spots," "patch worm," and "black holes." This defect is caused by one of the timber beetles or ambrosia beetles, which makes successive attacks in the living healthy sapwood from the time the trees are 20 or 30 years old until they reach the maximum age. Thus the black-hole and stained-wood defect is scattered all through the wood of the best part of the trunks of the trees. The average reduction in value of otherwise best-grade lumber amounts, in many localities, to from 25 to 75 per cent. The defect is commonly found in oak and elm furniture and in interior hardwood finish in dwellings and other buildings.

*The locust borer.*—The locust, as is well known, suffers to such an extent from the ravages of the locust borer that in many localities the trees are rendered worthless for commercial purposes or they are reduced in value below the point of profitable growth as a forest tree; otherwise this would be one of the most profitable trees in the natural forest or artificial plantation and would contribute greatly to an increased timber supply.

*Turpentine beetles and turpentine borers.*—While the softwood trees, or conifers, suffer far less than the hardwoods from the class of enemies which cause defects in the living timber, there are a few notable examples of serious damage. There is a common trouble affecting the various species of pine throughout the country known as basal wounds or basal fire wounds. It has been found that a large percentage of this injury to the pine in the States north and west of the Gulf States and in the Middle and South Atlantic States is caused by the red turpentine beetle and in the Southern States by the black turpentine beetle. These beetles attack the healthy living bark at and toward the base of the trunks of medium to large trees and kill areas varying in size from 1 to 10 square feet. These dead

areas are subsequently burned off by surface fires and are then generally referred to as fire wounds. The further damage to the exposed wood by successive fires, decay, and insects often results in a total loss of the best portion of the tree, or a reduction in value of the lower section of the trunk of from 10 to 50 per cent. These and similar wounds in the bark of trees, including those caused by lightning and by the uncovering and exposure of the wood in turpentining, offer favorable conditions for the attack of the turpentine borer, the work of which, together with that of two or three others with similar habits, is very extensive, and causes losses amounting to from 10 to 50 per cent of the value of the wood of the best part of the trees thus affected.

*The white pine weevil.*—The abnormal development of white pine trees as the result of successive attacks on the terminals of the saplings and young trees by the white pine weevil is an element of loss of considerable importance, especially in mixed stands and in open pure stands of this timber. The value of such trees is reduced from 20 to 50 per cent below those of normal development, and there is an additional loss from the effect of their spreading branches or crowns in the suppression or crowding out of trees which would otherwise occupy the space thus usurped.

There are many other examples of insects which damage the wood and bark of living trees, but those mentioned should be sufficient to demonstrate the importance of insects in this relation.

## CONTROL OF INSECTS WHICH CAUSE DEFECTS IN LIVING TIMBER.[a]

The class of insects which cause defects in the wood of living timber can be controlled to a greater or less extent, depending upon local conditions, and a large percentage of the losses prevented through the adoption of certain requisite details in forest management, among which the following are especially important:

(1) The utilization of all of the defective and infested timber that will pay expenses for manufacture into merchantable products, such as lumber, cordwood, etc.

(2) The burning of infested timber and waste material not available for use, including dead standing and fallen timber, to remove the breeding places of insects like the oak timber worm and the chestnut timber worm, which go from the dead to the living timber.

(3) The prevention of wounds of any kind in the bark of living trees.

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[a] For methods of controlling the locust borer and white pine weevil, see Circulars 83 and 90, respectively, of the Bureau of Entomology, U. S. Department of Agriculture.

(4) The prevention of future losses by the practice of improved forestry methods to eliminate favorable conditions for injury and contribute to a perpetual supply of vigorous, healthy timber to be utilized before it passes the stage of profitable increment.

It should be remembered that the different species of insects which cause defects in the wood of living timber require different details in the methods of control, and that special cases, special local conditions, and details in business methods and requirements determine which one of the available methods should be adopted.

It should also be remembered that in the more important cases much loss of time and money may be prevented and the best success attained by first securing some authoritative advice on the insects involved and the specific requirements for the control work.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *October 7, 1910.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# INSECT INJURIES TO THE WOOD OF DYING AND DEAD TREES.[a]

By A. D. HOPKINS,

*In Charge of Forest Insect Investigations.*

Timber dying from insect attack and other causes, including fire, disease, storms, etc., is attacked by certain wood-boring insects which extend their burrows through the sound sapwood and heartwood, and thus contribute to the rapid deterioration and decay of a commodity which otherwise would be available commercially during periods of from one to twenty years or more after the death of the trees, depending on the species of trees and on the character of the product desired. This loss often amounts to from 25 to 100 per cent during the period in which the dead timber would otherwise be almost as valuable as if living.

### CONIFEROUS TREES.

*Sawyers.*—One of the most striking examples of the destruction or deterioration of the wood of dying and dead timber, familiar to all lumbermen, is the injury to fire-killed and storm-felled pine, fir, spruce, etc., caused by boring larvæ known as "sawyers." These borers hatch from eggs deposited by the adult beetles in the bark of the dying trees, and after feeding on the inner bark for a time they enter the solid wood and extend their large burrows deep into the heartwood. Fire-killed white pine is especially liable to this injury, and is often so seriously damaged within three or four months during the warm season as to reduce the value of the timber 30 to 50 per cent. The shortleaf, loblolly, and longleaf pines of the Southern States are

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, 1909.

damaged to a somewhat less extent, but instances are known in which more than one billion feet of storm-felled timber within limited areas were reduced in value 25 to 35 per cent within three months after the storm. The fire-killed and insect-killed sugar pine, silver pine, and yellow pine of the western forests are also damaged in a similar manner and the value of the product greatly reduced within a few months after the trees die. The aggregate losses from this secondary source in the coniferous forests of the entire country contribute largely to the annual waste of millions of dollars' worth of forest products which otherwise might be utilized.

*Ambrosia beetles.*—Wood-boring insects of another class, known as timber beetles or ambrosia beetles, cause pinhole defects, principally in the sapwood, although some of them extend their burrows into the heartwood. These insects make their attack in the early stage of the declining or dying of the tree, or before the sapwood has materially changed from the normal healthy condition, and often in such numbers as to perforate every square inch of wood. Thus the wood is not only rendered defective on account of the presence of pinholes, but the holes give entrance to a wood-staining fungus which causes a rapid discoloration and produces still further deterioration of the product.

The sapwood of trees dying from the attack of other insects or from fire, storm, or other causes is often reduced in value 50 per cent or more, and in some cases the value of the heartwood is reduced in a like manner from 5 to 10 per cent.

*Pinhole borers in cypress.*—An example of the destructive work of insects which attack dying and dead trees is found in the cypress in the Gulf States, where these trees are deadened by the lumbermen and left standing several months, or until the timber is sufficiently dry to be floated. Upon investigation it was found that trees deadened at certain seasons of the year were attacked by the ambrosia beetles, or pinhole borers, and that in some cases millions of feet of timber had been reduced 10 to 25 per cent or more in value.[a]

### HARDWOOD TREES.

*Roundheaded borers, timber worms, and ambrosia beetles.*—The principal damage to dying and dead hardwood trees is caused by certain roundheaded wood-borers (Cerambycidæ) with habits similar to the sawyer, by the timber worms mentioned as damaging living timber, and by ambrosia beetles having habits similar to those that attack the sapwood and heartwood of conifers. All of the hardwoods suffer more or less, but the greatest damage is done to the wood of hickory,

[a] For methods of preventing pinhole injury to girdled cypress see Circular No. 82 of the Bureau of Entomology, U. S. Department of Agriculture.

ash, oak, and chestnut, which are often reduced in value 10 to 25 per cent or more within the period in which it would otherwise remain sound and available for commercial purposes.

### PREVENTION OF INJURY TO DYING AND DEAD TREES.

A large percentage of the injury to the wood of insect, fire, and lightning killed trees and those killed or dying from injuries by storms, disease, etc., can be prevented as follows:

(1) By the prompt utilization of such timber within a few weeks or months after it is dead or found to be past recovery.

(2) By removing the bark from the merchantable portions of the trunks within a few weeks after the trees are dead (the work to be done either before or after the trees are felled).

(3) By felling the trees and placing the unbarked logs in water.

(4) By the adoption of a system of forest management which will provide for the prompt utilization of all trees which die from any cause.

Approved:
JAMES WILSON,
*Secretary of Agriculture.*

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L. O. HOWARD, Entomologist and Chief of Bureau.

# INSECT INJURIES TO FOREST PRODUCTS.

BY

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*In Charge of Forest Insect Investigations.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# INSECTS IN THEIR RELATION TO THE REDUCTION OF FUTURE SUPPLIES OF TIMBER, AND GENERAL PRINCIPLES OF CONTROL.[a]

By A. D. HOPKINS,
*In Charge of Forest Insect Investigations.*

Insects not only reduce future supplies of timber by killing the mature trees and destroying the wood of timber that is inaccessible for utilization, but through injuries inflicted upon trees during the flowering, fruiting, germinating, seedling, and sapling periods of early growth they prevent normal reproduction and development.

### INTERRELATIONS OF FOREST INSECTS AND FOREST FIRES.

Investigations conducted by the writer and assistants in all sections of the country during the past ten years indicate to them quite conclusively that the average percentage of loss of merchantable timber in the forests of the entire country to be charged to insects during a five or ten year period is infinitely greater than most people realize.

*Losses from forest insects.*—The writer estimates that for a ten-year period the average amount of timber in the forests of the entire country killed and reduced in value by insects would represent an average loss of $62,500,000 annually.[b]

It has been estimated that the Black Hills beetle killed approximately 1,000,000,000 feet B. M. of timber during a period of ten years, which at $2.50 per thousand would amount to an average of $250,000 annually. This is merely one example of very destructive depredations by a single species of barkbeetle in a single National Forest.[c]

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, United States Department of Agriculture.

[b] *Losses from forest fires.*—It has been estimated that "on the average, since 1870, forest fires have yearly cost $50,000,000 in timber." (Cleveland, T., jr., Circular 167, Forest Service, United States Department of Agriculture, p. 3.)

[c] It has been estimated that the losses of timber from forest fires on all of the National Forests of the United States from 1905 to 1908, inclusive, average only $165,062 annually. (Cleveland, T., jr., Yearbook United States Department of Agriculture for 1908, p. 541.)

Prof. Lawrence Bruner, state entomologist of Nebraska, at a meeting of the American Association of Economic Entomologists, held at Baltimore, Md., in December, 1908, spoke as follows: "I can agree with Doctor Hopkins that the insects are far more important in destroying our forests than fires."

*Insect-killed timber as fuel for fires.*—It has often happened that after insects have killed the timber over extensive areas the standing and fallen dead trees furnished fuel for great forest fires which have not only destroyed or charred the dead timber but killed the living timber and reproduction and swept on into adjacent areas of healthy timber. Indeed, abundant evidence has been found during recent investigations to indicate that some of the vast denuded areas in the Rocky Mountains and other sections of the country are primarily due to widespread devastation by insects, and that subsequent fires destroyed the timber and prevented reproduction.

It is also evident that a considerable percentage of dead timber, and especially that found in coniferous forest regions, which has generally been believed to have been fire-killed is a result of primary attack by insects. This has been demonstrated in many cases by the pitch-marked galleries of the destructive barkbeetles on the surface of the wood of the old dead trees which had escaped subsequent fires.

*Fire-killed timber injured by insects.*—It is true that a vast amount of timber has been killed outright or has died as the direct result of forest fires, but in almost every case observed insects have contributed to a greater or less extent to the death of recently fire-injured trees which might otherwise have recovered, and especially to the rapid deterioration of the wood of a large percentage of the injured and killed trees. It is evident that in some cases fire-scorched and fire-killed timber has contributed to the multiplication of one or more of the insect enemies destructive to living timber, and thus the injury started by the fire may have resulted in a destructive outbreak of beetles. However, it is evident that this has happened only when the destructive beetle was already present in abnormal numbers in the forest surrounding the fire-swept area. Therefore, *it is believed that injuries by fire are not as a rule an important factor in contributing to subsequent depredations by barkbeetles.* Such fires, however, contribute to the multiplication of the insects which depredate on the bark and wood of dying and dead trees, so that in forested areas where fires are frequent the damage to the wood of such trees is more severe, and fewer injured trees recover on account of the abundance of secondary barkbeetle enemies which do not, as a rule, attack and kill living timber.

*Destruction of insects by fire.*—There is another important feature in the relation of insects and fire, in which the fire contributes to the destruction of the principal barkbeetle enemies of the living timber.

This happens when the fire burns the timber while it is infested, thus effectually destroying the broods of the insects. It is perfectly plain that the dying and dead foliage of the beetle-infested trees and the dead bark on the trunks would contribute to the spreading of crown fires and thus the bark on the entire infested trunks would be sufficiently scorched to kill the insects. Therefore, complete fire control may easily contribute to more extended depredations by insects on the living timber, thus increasing, rather than diminishing, the need for insect control. However, the setting of fires or permitting them to burn for the purpose of combating insects should never be undertaken or permitted.

*Durability of insect-killed timber.*—Some of the matured larch trees which evidently died as a result of defoliation by the larch worm between 1881 and 1885, and which had escaped subsequent depredations by fire and wood-boring insects, were found by the writer in 1908 to be standing and sound enough to be utilized for railroad ties and many other purposes. Under similar conditions the heartwood of red spruce and white pine in the East, of Engelmann spruce in the Rocky Mountains, and of Douglas fir in the Northwest coast region have been found by the writer to be sound enough for profitable utilization for pulp wood, lumber, fuel, and other purposes from twenty to thirty years after it had been killed by insects or fire. Thus it is shown that timber killed by insects and fire would be available for utilization for many years were it not for injuries through the secondary attacks of wood-boring insects and the destruction of insect-killed timber by forest fires.

## INTERRELATION OF FOREST INSECTS AND FOREST FUNGI.

*Decay following injury by insects.*—It is well known that the burrows in the bark and wood of living and dead trees and in the crude and finished products often contribute to the entrance of bark and wood decaying fungi. Deterioration and decay are thus far more rapid than would otherwise be possible. It is also known that trees injured and dying from primary attack by parasitic fungi are attractive to certain insects which breed in the bark and wood of sickly and dying trees, and that certain other complicated troubles affecting forest trees are the result of an intimate interrelation and interdependence of insects and fungi. There can be no doubt, however, that certain species and groups of both insects and fungi are independently capable of attacking and killing perfectly vigorous and healthy trees.

## SUMMARY AND ESTIMATES RELATING TO CHARACTER AND EXTENT OF INSECT DAMAGE.

The killing of trees by insects; the damage by them to the wood of living, dying, and dead timber; the destruction of insect-killed timber by subsequent forest fires; the damage to fire-killed timber

by insects; and the damage from decay resulting from insect injuries to the wood, have all been more or less continuous for centuries and are still going on in the forest and woodland areas of this country.

While these depredations are not always evident or important in all forests or localities, yet almost every year, somewhere in the forests of the country, there are widespread depredations.

In every forest and woodland there is an ever present but inconspicuous army of insects which require the bark, wood, foliage, and seeds of the various tree species for their breeding places or food. Thus, the accumulated but inconspicuous injuries wrought during the period required for the growth of a tree to commercial size go far toward reducing the average annual increment below the point of profitable investments.

The accumulated damage to crude, finished, and utilized products reduces the profits of the manufacturer, increases the price of the higher grades to the consumer, and results in an increased drain on the natural resources.

In any attempt to estimate in *feet, board measure*, or *dollars*, the extent of losses or waste of timber supplies caused by insects there are many conflicting factors which contribute to the difficulty of arriving at accurate conclusions. The published information concerning the amount in board feet of standing timber in the country is admittedly only an estimate, as are also the published data relating to average stumpage value. The published statistics relating to the amount and value of forest products are of course more accurate, but until more complete data can be furnished by the forest experts on the various complicated phases of forest statistics any figures given by the forest entomologist relating to the value of timber and commercial products destroyed or reduced in value by insects must be considered on the same basis as the other estimates, and as the best that can be presented on available evidence.

*Standing timber killed and damaged by insects.*—When we consider the amount of standing merchantable timber killed by insects and the amount of standing timber, living, dying, and dead, which has been reduced in quantity and value through their agency during a ten-year period, we would estimate that such timber represents an equivalent of more than 10 per cent of the quantity and stumpage value of the total stand of merchantable timber in the United States at any given time.[a] A certain percentage of such timber is a total

[a] The estimate of the area and stand of the present forests of the United States, as given in Circular 166 of the Forest Service, page 6, is two trillion five hundred billion feet (2,500,000,000,000) board measure. The average stumpage value has been given as $2.50 per one thousand feet b. m., making a total value of the standing merchantable timber of $6,250,000,000. Ten per cent of this amount would be $625,000,000, as the amount to be charged to in-

loss because of the impossibility of utilization; but in some cases a greater or less percentage can be, and in some cases is, utilized within the period in which it is of sufficient value to yield a profitable return on the cost of logging and manufacture, although its value is greatly reduced.

*Reduction in the Nation's wealth.*—When we consider the forest resources both in merchantable timber and young growth as an important asset of the Nation's wealth; as representing a given value to the people for direct utilization; as a cover to the soil for protection of the land from erosion; as protection of headwater streams and of game; and as contributing to the æsthetic value of health and pleasure resorts, it would be difficult indeed to estimate the amount or percentage of loss of timber or the reduction in the land values, in each case, chargeable to insects. It is plain, however, that in the aggregate it is considerably greater than when estimated on stumpage values alone.

*Reduction in cash revenue.*—When we consider the problem from the standpoint of direct utilization we can estimate the annual loss on a basis of mill values; but here again we meet with complications, since much of the damaged material is left standing or is discarded in the woods or at the mill without measurement. Therefore we are left to judge from our observations and knowledge of the general conditions as regards dead and damaged timber found in the forests of the country, and the information from lumbermen in different sections, as to the percentage of loss from defective timber. On this basis we can estimate that the amount of insect-killed and damaged timber left in the woods, plus the reduction in value of that utilized, to be charged to insects is not far from an equivalent of 10 per cent of the value of the annual output of forest products of all kinds, in the rough. The total value of the forest products of the United States in 1907 is given as $1,280,000,000; the losses from insect depredations would therefore represent an annual loss in a cash value of more than $100,000,000.

*Reduction in value of finished and commercial products.*—When we consider the aggregate loss to the manufacturers of the finished products, to the trade, and to the consumer from insect injuries to the wood, it is evident that it amounts to many millions of dollars in addition to the estimated loss of crude products, or at least 3 per cent of the mill value.

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sects for a ten-year period, or an average of $62,500,000 annually. As an example, it has been estimated that over 1,000,000,000 feet b. m. of timber was killed by the Black Hills beetle in the Blacks Hills National Forest within a period of ten years. This, at $2.50 per one thousand feet stumpage, would be an average of $250,000 annually in a single forest of 1,294,440 acres.

## METHODS OF PREVENTION AND CONTROL.

The results of extensive investigations and of practical applications of the knowledge gained during recent years have demonstrated that some of the most destructive insect enemies of American forests and of the manufactured and utilized products can be controlled, and serious damage prevented, with little or no ultimate cost over that involved in forest management and business methods.

There are, of course, certain insects and certain injuries which, under present conditions and available information, can not be controlled or prevented, but it is very evident that if the information now available through the publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it will result in the prevention of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years, and thus contribute greatly to the conservation of forest resources.

### General Principles of Control.

The ordinary spraying and similar methods employed in dealing with fruit and shade tree insects are, of course, not available for practical application in the case of forest trees. But there are other and less expensive methods of accomplishing the desired results.

In all efforts to control an outbreak or prevent excessive loss from forest insects it should be remembered that as a rule it is useless to attempt the complete extermination of a given insect enemy of a forest tree or forest product. Experience has demonstrated that it is only necessary to reduce and weaken its forces 75 per cent or more. It can not then continue an aggressive attack, but must occupy a defensive position against its own enemies until conditions resulting from avoidable negligence and mismanagement by the owners of the forests and manufacturers of forest products favor its again becoming destructive. Forest insects can thus be easily kept under control by good management.

The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work.

It is, however, of the utmost importance that any adjustment or modification in management or business methods should be based on

expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved and the essential features of the methods for their control. This should be supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources, and still further supplemented by practical knowledge and experience relating to local conditions and facilities favorable and unfavorable for success in practical applications according to the recommended method or policy of control.

As has been shown, the mature or merchantable timber is the most susceptible to injury or death from the ravages of insects. Therefore, considered from the standpoint of insect control and the prevention of one of the greatest items of loss, it is important that such matured timber should be utilized before it begins to deteriorate, or before it reaches the stage of unprofitable growth.

For the greatest success in dealing with forest insects, it must be recognized that there are certain features in the habits and seasonal history of each species which differ to a greater or less extent from those of all other species, even of the same genus; that there are certain features in the characteristics of the various species of trees which differ from those of all other species; and that as a rule it is the technical knowledge of these peculiar features or characteristics of the trees and their enemies which furnishes the clew to successful methods of control.

There are also many peculiar features in the prevailing conditions in different localities, some of them favorable, others unfavorable, for the practical application according to a given method, so that while certain general advice may apply in a broad sense and be available for utilization by the practical man, whether owner, manager, or forester, without further advice, it is often necessary to diagnose a given case before specific expert advice can be given as to the exact cause and the most effective method or policy to be adopted, just as a physician must diagnose a case of illness or injury before prescribing the required treatment for his patient.

Therefore, in a consideration of the problem as to how far the waste of forest resources caused by insects can be prevented and how far the damaged timber can be utilized, we will attempt to give only general statements based on the results of our observations relating to some of the principal kinds of loss discussed in Circulars 125 to 128, inclusive, of this Bureau. In addition, we will consider in this circular the utilization of natural enemies of injurious insects and the utilization of waste caused by insects.

## Utilization of Natural Enemies and Factors in the Control of Injurious Insects.

Were it not for the natural checks and natural factors of control of some of the more destructive insect enemies of forest trees and forest products, artificial control would in many cases be impossible, and the depredations would evidently be far more continuous and complete. These natural factors in the control of the depredating insects consist of parasitic and predatory insects, diseases of insects, birds, adverse climatic conditions, etc. While one or more of these beneficial factors exert a continuous and powerful influence toward the prevention of a much greater waste of forest resources, it has been repeatedly demonstrated that they can not be depended on to prevent widespread devastations or to otherwise work for the best interests of the private or public owner by protecting the best trees and the best tree species. The insects and birds which prey upon the depredating insects also have factors to contend against, consisting of insects, birds, diseases, and climatic conditions. Therefore under normal conditions the tendency is toward the preservation of a balance between the warring factors, but frequently the enemies of the trees get the ascendancy and take on the character of an invasion, which may continue for two or three or even ten years before the balance is again adjusted through the influence of the natural enemies or diminished food supply. Thus a vast amount of timber or of a given forest product may be destroyed before the factors of natural control can prevail.

It is evident that the most effective utilization of the agencies of natural control will be through the alliance with them of the owner of the forest by his efforts toward an artificial reduction of the enemies of the trees rather than by efforts to make the natural enemies of the injurious insects his allies through artificial introduction or dissemination. The former is accomplished by the adoption of methods of combating the invaders which will reduce and weaken their forces below their power of prosecuting aggressive movements and attacks, or, as previously stated, to reduce their numbers to the point where they must occupy a defensive position against their natural enemies and be dependent for their supplies of food and breeding places upon that furnished through avoidable mismanagement of the forests and manufacturing operations. Thus the owner of the forest can contribute greatly toward the preservation of a balance which will be to his material benefit. On the other hand, he may in the future, as in the past, contribute greatly to the multiplication of the depredating insects and to greatly increased losses caused by them through neglect or a disregard of available information on the fundamental principles of insect control in the management of forests and manufacturing enterprises.

### BENEFICIAL INSECTS.

The beneficial insects comprise those which are internal or external parasites of the immature or mature stages of the injurious insects, and predators which feed on the young or adults of insects either before or after they make their attack on the trees or products. These two beneficial factors are doubtless far more effective in the long run than any other agencies of natural control. Yet they, in combination with all other factors, can not be relied upon to render continued and efficient control. They can, however, be relied upon to respond to artificial assistance in reducing the numbers of the depredators.

### BENEFICIAL DISEASES OF INSECTS.

It is very evident that the parasitic fungi and bacteria which sometimes cause epidemics among injurious insects often exert a powerful influence toward the control of extensive outbreaks or invasions of insect enemies of forests. Indeed, it appears that the greatest service rendered by this class of natural enemies is in the frequent sudden appearance of an epidemic which kills off a destructive species of insects after the latter has increased to such numbers and extended its depredations over such vast areas as to be far beyond the control of man or his insect and bird allies. Numerous examples of this kind of natural control are found in the sudden ending of widespread depredations by various species of caterpillars and sawfly larvæ which defoliate deciduous and coniferous trees. As a rule, however, the beneficial effects of the diseases of insects prevail only after the injurious insects have increased to excessive numbers. Therefore this factor of insect control can not be depended upon to hold the insects in check or prevent outbreaks. The fact, however, that it operates on a class of insect enemies of the forest (defoliators) which at present can not be controlled by any known artificial methods renders the services of the diseases all the more valuable.

It is believed that with further knowledge of nature's method of propagating, perpetuating, and disseminating the diseases which cause epidemics among insects they may be utilized more or less successfully through artificial propagation and dissemination to prevent threatened invasions of defoliating insects.

### BENEFICIAL BIRDS.

It is very evident that certain kinds of birds, such as woodpeckers, render valuable service toward the natural control of destructive bark and wood boring insects. They appear to render the greatest service, however, where but few trees are being killed or injured, because their concentrated work on such trees may contribute toward the prevention of an abnormal increase of the insects. They also

render some service as allies of the other beneficial factors which assist in artificial control. It is evident, however, that where many hundreds or thousands of trees are being killed the comparatively limited number of birds in any forest under the most favorable conditions could have little or no beneficial effect. Therefore, while the birds should be classed among the valuable friends of the forest, and should be protected, it is plain that they can not, even with the utmost protection, be relied upon to protect the forest against destructive ravages of insects.

We must remember, in this connection, that there are complicated interrelations between birds, injurious insects, and beneficial insects which do not necessarily operate to the benefit of the forest. In fact, it may sometimes be quite the reverse. Therefore, in order to derive the greatest benefit from the conflict between the birds, the insect enemies of the trees, and the insect friends of the trees, we must utilize our knowledge of the factors which are contributing toward the preservation of a balance, so that whenever the enemies of the forest threaten to get beyond natural control we may enter the field through artificial means and endeavor to force them back to their normal defensive position.

### BENEFICIAL CLIMATIC CONDITIONS.

The benefits to be derived from climatic conditions which are detrimental or destructive to insect enemies of the forest, while sometimes very great, are necessarily unreliable, and thus can not be depended upon to assist in artificial control. In fact, the very condition which may contribute to the destruction of one depredator may favor the multiplication of another.

### UTILIZATION OF WASTE CAUSED BY INSECTS.

When we come to consider the vast amount of standing timber in the forests of the country which has been injured or killed by insects, and will go to waste if it is not utilized within a limited period, we realize that there are great possibilities in its utilization as a means of preventing the reduction of future supplies of living healthy timber. It is all the more important that the insect-infested timber should be utilized, because in so doing we can contribute more perhaps than in any other way to the reduction of the insects to or below their normal numbers, and thus provide against serious injury in the future, as well as to the maintenance of control.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *October 7, 1910.*



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L. O. HOWARD, Entomologist and Chief of Bureau.

# THE OAK PRUNER.

BY

F. H. CHITTENDEN, Sc. D.,

*In Charge of Truck Crop and Stored Product Insect Investigations.*

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CIRCULAR No. 130. Issued December 10, 1910.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE OAK PRUNER.[a]

(*Elaphidion villosum* Fab.)

By F. H. Chittenden,

*In Charge of Truck Crop and Stored Product Insect Investigations.*

### INTRODUCTORY.

Many sorts of trees, particularly oak and hickory, grown for shade are often noticed with their limbs severed as if with a knife or saw. Underneath these trees numbers of twigs and small branches strew the ground. The severed limbs are from a few inches to 2 or 3 feet long, and on one occasion a limb was seen that measured 10 feet in length and another that was 1¼ inches in thickness. Young trees are sometimes felled. An examination of one end, sometimes of both ends, of a severed limb will show a smoothly cut surface near the center of which will be seen a more or less oval opening plugged with fine shavings and sawdust (fig. 1, *e*, *f*).

### DESCRIPTIVE.

If one of these limbs be split open at the proper time a soft-bodied larva, resembling that shown in figure 1 at *a*, will be found. This is the larva of the oak pruner. It is nearly cylindrical, soft and fleshy, of a whitish or light yellowish color, and is provided with rudimentary legs (fig. 1, *g*).

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[a] Formerly the species under consideration was known under two names, *Elaphidion villosum* Fab. and *E. parallelum* Newm. The writer, however, has seen an abundance of specimens of what are labeled by both names, and while it may be true that there are two species it is certain that the species which breed in the North from the amputated twigs are identical, since the writer has reared both what are known as *villosum* and *parallelum* from such twigs. That which breeds in the portion remaining on the tree has not been investigated, but it is probably not different.

Horn believed the two species identical and his opinion should not be disputed until the contrary can be proved.

The beetle which produces this larva is slender and cylindrical, dark brown, and clothed with grayish, somewhat mottled pubescence. The antennæ of the female are shorter, those of the male (illustrated at *b*) longer, than the body; the proximal joints are armed with small spines. Each elytron terminates in two small spines and the femora or thighs are unarmed. The length of the body varies from about one-half to three-fourths of an inch.

## DISTRIBUTION.

Available records show that the typical oak pruner (*Elaphidion villosum* Fab.) occurs from New England westward to Michigan, and probably farther west, and southward through the District of Columbia and Virginia to North Carolina, while there are specimens in the United States National Museum labeled Texas. It is therefore evident that the species covers the greater portion of the eastern United States, with the possible exception of Georgia and one or two of the Gulf States, from which the typical form has not been seen.

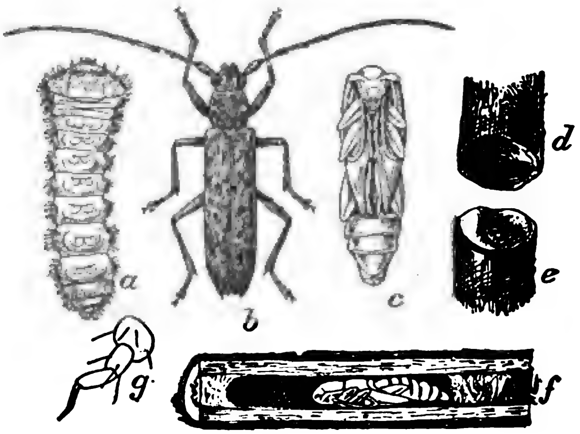


FIG. 1.—The oak pruner (*Elaphidion villosum*): *a*, Larva; *b*, beetle; *c*, pupa; *d*, end of twig cut by larva from tree; *e*, reverse end containing insect; *f*, same from side, split to show pupa within; *g*, leg of larva. *a*, *b*, *c*, About twice natural size; *d*, *e*, *f*, natural size; *g*, greatly enlarged. (Author's illustration.)

## FOOD PLANTS AND INJURY.

The list of food plants of this species includes oak, hickory, pecan, chestnut, maple, fir (Abies) (doubtful, recorded by Haldeman), locust, elm, redbud (*Cercis canadensis*), apple, plum, peach, pear, quince, grape, orange, Osage orange (*Maclura aurantiaca*), wistaria, climbing bittersweet (*Celastrus scandens*), black walnut, sweet gum, and hackberry, according to the records of the Forest Insect Investigations of this Bureau. Indeed, this insect or allied species will attack almost every form of deciduous trees, shrubs, and vines with woody stalks. The pruned twigs of various trees and shrubs are of frequent occurrence, and among those which have been noted by the writer in the vicinity of the District of Columbia and in New York are the spicebush (*Lindera benzoin*), sassafras, sumac, English or white walnut, and beech. Since no other species of insect in the regions

specified is known to have the same pruning habit, it is practically certain that the species under discussion is the culprit.

Of injuries by this species, it has been reported that in 1886 "peach trees in portions of Michigan were seriously injured. The twigs were cut off so as to nearly destroy some of the trees." In 1892 the extraordinary abundance of this pruner in Pennsylvania, New Jersey, and neighboring States attracted considerable attention. At that time carloads of the branches could be gathered up from the ground throughout the oak forests in Bucks County, Pa. One of the striking features noticeable that year in riding through that part of the country lying between Washington, D. C., and New York City was the unusual amount of injury by Elaphidion on oaks. In some localities every tree had several dead or dying twigs, and the ground beneath was strewn with branches which had been damaged by this species and later broken off by the wind.

In the writer's experience the oak pruner was extremely abundant in years past in the neighborhood of Ithaca, N. Y., and near South Woodstock, Conn., on the shagbark hickory, the severed twigs and branches occurring by the barrelful under a single tree. In one instance a pear orchard at Ithaca, N. Y., had been very extensively pruned. The insect had apparently attacked healthy living twigs and several trees had every appearance of having been killed outright.

A few of the injurious and other occurrences reported to this Bureau during the past decade may be mentioned: Regarding supposed damage to oak, Mr. R. A. Edwards, of Peru, Ind., wrote on March 27, 1901, that he could not observe that the pruner did actual damage beyond cutting off the smaller branches, some of which do not reach the ground, but hang from the limb or lodge upon limbs below and there die. September 5, 1902, Mr. Edmund L. Tyler, of Anniston, Ala., sent a limb of hickory nearly 5 feet in length which had been pruned 3 feet from the end by the oak pruner. The point at which amputation had taken place was an even inch in diameter. April 25, 1903, Mr. Albert M. Boozer, of Columbia, S. C., sent this species, which he thought to be injurious to pecan in that vicinity. It was probably merely concerned in more serious injury due to the pecan twig-girdler (*Oncideres cingulata* Say) and to branch and trunk borers. Mr. E. J. Vann, of Madison, Fla., stated, in a letter dated July 28, 1905, that what he considered this species had almost ruined dwarf chestnuts in that vicinity. Miss Alice S. Hainsworth, of South China, Me., wrote, July 30, 1906, that this species was destroying the beauty of oak trees in that vicinity. The lawn beneath the oak trees was continually strewn with fallen branches. In 1907 report of injury to oak in South Carolina was received. During 1908 the depredations by this species were widespread and general,

injury having been reported in Massachusetts, Pennsylvania, Virginia, and Kansas to oak, elm, pear, and wistaria. The year following pecans were attacked in Alabama and Mississippi, and hickory and oak in Illinois. In 1910 the oak pruner attracted widespread attention in the States of New York, Connecticut, and Massachusetts and became the subject of many newspaper notices under the name of the "gun-worm."

## LIFE HISTORY.

From present knowledge of this species the following brief account of its life history may be given:

In the northern portion of the upper austral life zone the adult appears in early summer. The mother beetle inserts an egg, usually in one of the smaller twigs of a living tree. The young larva hatching therefrom first attacks the wood under the bark, following the grain of the wood and packing its burrow with its sawdust-like castings. The larva, as it grows, bores toward the base, often consuming the wood entirely around the limb and ejecting its castings through holes which it makes in the bark. Later it follows the axis of the twig, boring through the center and excavating a more or less oval channel, sometimes for a distance of several inches. Dr. Asa Fitch[a] has said that the larva is only about half grown when it severs the limb in which it is working, but it has more probably attained its full growth at this time. He described this operation, recounting at length how, with "consummate skill and seemingly superterrestrial intelligence, he varies his proceedings to meet the circumstances of his situation in each particular case."

From Fitch's account it would seem that he imputed to this insect a reasoning power, which enables it to modify its operations according to conditions and to judge just how far the limb should be cut off to insure its ultimate amputation by the wind without endangering its own safety. Whether guided by reason or by blind instinct, the insect is actually enabled to accomplish this purpose.

After cutting away the wood in such manner that the winds will in time bring the limb to the ground, the contained larva retreats into its burrow and plugs up the severed end with castings. Here it transforms to pupa (fig. 1, *c*, *f*), sometimes late in the autumn and often not until early spring, assuming the adult stage as early as November and appearing abroad in June and throughout the summer until September.

A larva received from South Woodstock, Conn., transformed to pupa May 3 and to adult May 21, having thus passed the pupal stage in eighteen days, the average temperature having been about 74° F.

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[a] FITCH, ASA.—Fifth Report on Insects New York, pp. 797–804, 1859.

Although this species normally completes it transformations in amputated or fallen limbs, it occasionally breeds in limbs that have not been severed. It does not always cut off the twigs in which it lives, and the larva sometimes reverses the order of proceedings and directs its burrow toward the distal end of the branch, which it cuts off at the end of its burrow and remains in the branch attached to the tree.

From the earlier accounts of Fitch and others it would be inferred that the insect requires a single year only for the completion of its life cycle. Dr. John Hamilton,[a] however, has stated that a longer period is required, three years being the usual time, and in individual cases four or more years being consumed. The writer is strongly inclined to believe such exceptionally long periods, even three years, to be the result of undue dryness caused by unnatural indoor conditions.

### WHY THE LARVA AMPUTATES A LIMB.

The purpose of the larva in cutting away the wood furnishes an interesting topic for speculation. The object attained is its ultimate fall to the ground.

Peck, who wrote of this species in 1819,[b] thought that the limb, if permitted to remain attached to the tree, would become too dry and that a certain degree of moisture was required for the development of the insect, and that the limb was accordingly partially severed that it might eventually fall, and that then, lying on the ground amid the autumn leaves and beneath the winter's snow, the requisite degree of moisture was insured. In this belief Fitch concurred. Mr. Frederick Clarkson, however, took issue with Fitch, believing that the main object of the larva is to obtain deadwood and to prevent the flow of sap. Here we have two contrary views expressed—one that the object is to obtain moisture, the other to prevent it.

Such an excess of moisture as is obtained on the ground under the melting snow and the pools of water that collect in winter under the infested trees could hardly be a necessity in the life history of any terrestrial animal. The ease with which these insects may be reared from dry twigs indoors is conclusive proof to the contrary. Why they should require more moisture than fifty or a hundred others that could be named that have similar food habits and do not breed exclusively in fallen limbs it would be difficult to explain. Again, that the small flow of sap of oak or hickory could seriously interfere with development would seem unreasonable when we consider that these insects

[a] HAMILTON, JOHN.—Canadian Entomologist, vol. 19, pp. 141–145, 1887.

[b] PECK, WILLIAM D.—Mass. Agr. Repos. and Journ., vol. 5, pp. 307–313, Jan., 1819. (Treated as *Stenocoris putator* Peck. Not seen.)

are able to survive the immersion to which they are sometimes subjected for many days together during thaws and rainy spells in winter.

Another explanation of the limb's amputation occurs to the writer. Those who have reared beetles from hard wood can not have failed to observe that the larva before transforming cuts through the wood until it reaches the bark, which is left untouched and serves to protect the insect from marauding birds or other enemies. When the beetle develops it has only to gnaw its way through this thin layer of bark to effect its exit. There are undoubtedly some wood borers which are provided in the beetle state with mandibles sufficiently powerful to enable them to penetrate hard wood (Monohammus, for example), but the majority, among them Elaphidion, are not thus favored, and would be utterly unable with their weaker boring organs to escape, and would perish in their burrows had they not while larvæ excavated the necessary channel for their exit. These exit channels usually run at an angle to the axis of the wood. Now, in the case of our Elaphidion, which usually lives in a slender limb which it bores longitudinally, there is no room to place a branching, transverse channel; accordingly the larva severs the twig and when it becomes a beetle it cuts its way through the plug of castings.

As to Fitch's claim that the larva varies its operations to suit the different sizes of limbs, the average infested twig is of about the thickness of one's finger, and it is probable that the larva commences proceedings late in the season with the approach of cold weather when it is about full grown and ready for hibernation. To cut off the limb is a labor of some magnitude for so small a creature and may require several days for completion. It has a limited amount of energy, being now toward the end of its active existence as a borer, and the cooler weather serves to repress this energy, which is sufficient for cutting away all the wood in a small twig, but is inadequate for a larger one. The wood of a large branch is harder, and the insect ceases work, perhaps from exhaustion or from cold, or because its instinct impels it to cut a certain amount, and when that is accomplished to cease, its work being ended. At the close of his narrative Fitch says, in spite of a previous assertion that the insect never miscalculates, that—

in at least three-fourths of the fallen limbs no worm is to be found; and an examination of them shows that the insect perished at the time the limb was severed and before it had excavated any burrow upward in its center, no perforation being present except that leading into the lateral twig. It is probable that in many instances the limb broke when the insect was in the act of gnawing it asunder, either from its own weight or from a wind arising whilst the work was in progress.

## NATURAL ENEMIES.

As might be inferred from its manner of life, this insect enjoys as nearly perfect exemption from predaceous or parasitic attack as falls to the lot of most wood borers. Fitch, however, has stated that some of our insect-eating birds destroy the larvæ, and the writer has reared the parasite *Bracon eurygaster* Brullé from twigs inhabited by the species.

Among natural enemies of the oak pruner, Mr. F. H. Mosher[a] records the downy woodpecker (*Dryobates pubescens*), the blue jay (*Cyanocitta cristata*), and the black-capped chickadee (*Penthestes atricapillus*). Mr. W. L. McAtee, of the Bureau of Biological Survey, states that a species of Elaphidion is preyed upon by the downy woodpecker and by the great-crested flycatcher (*Myiarchus crinitus*). Mr. A. H. Kirkland[a] records having found a spider (*Theridium tepidariorum* C. Koch) feeding upon the mature insects.

## REMEDIES.

The pruning process is not always in itself especially injurious, since when the pruner occurs in only moderate numbers the vitality of the tree is not impaired. The ultimate effects, however, are likely to be more serious. The fallen twigs serve as a breeding place for hosts of other wood borers, many of which are injurious to shade trees and to standing timber. Some of these do not hesitate, in default of an abundance of dead or injured wood, to attack and damage apparently healthy living trees.

In case this species becomes injuriously abundant, it may be readily controlled by gathering the pruned twigs and burning them. This should be done from time to time, as otherwise they accumulate and make the lawn unsightly. To make this remedy of any value, the cooperation of neighbors is desirable. The work should be as thorough as possible. If the twigs are gathered in numbers during one season, the chances are that the insects will not be nearly so abundant the year following.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *October 14, 1910.*

[a] Forty-fifth Annual Rep. Sec. Mass. State Board Agr. for 1897 (1898), p. 244.



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BUREAU OF ENTOMOLOGY—CIRCULAR No. 131.

L. O. HOWARD, Entomologist and Chief of Bureau.

# HOW TO CONTROL THE PEAR THRIPS.

BY

S. W. FOSTER AND P. R. JONES,

*Agents and Experts.*

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CIRCULAR No. 131. Issued January 9, 1911.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# HOW TO CONTROL THE PEAR THRIPS.[a]

(*Euthrips pyri* Daniel.)

By S. W. FOSTER and P. R. JONES,
*Agents and Experts.*

## DISTRIBUTION.

The pear thrips (*Euthrips pyri* Daniel) (fig. 2) is at present confined to California and is very destructive throughout Santa Clara, Contra Costa, Solano, and Sacramento counties, with considerable areas infested in Alameda, Yolo, Napa, and Sonoma counties. (Fig. 1.) Reports of the presence of this species in other sections of California and in Oregon have been received, but each case was closely investigated and the insect in question found to be some other species. Bagnal[b] reports this insect in England; otherwise it is not known outside the State of California.

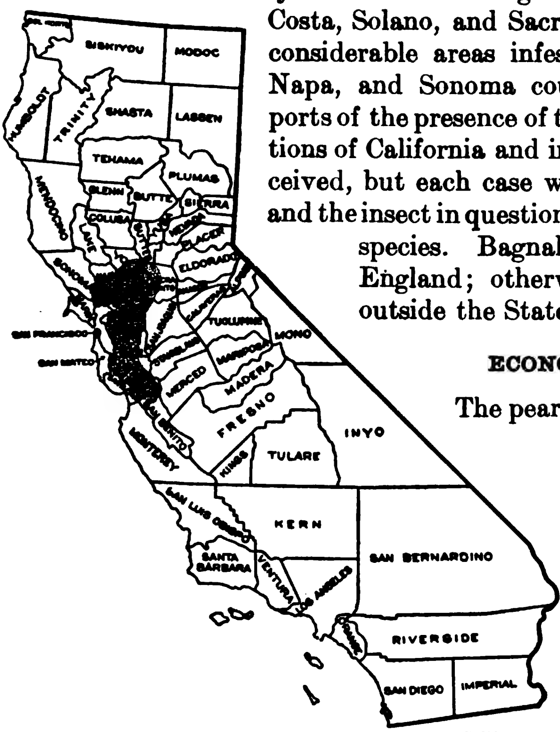


FIG. 1.—Map showing area infested by pear thrips in California. (Original.)

## ECONOMIC IMPORTANCE.

The pear thrips is at present tne most important insect pest with which the growers of deciduous fruits in the counties mentioned have to contend. On account of the minute size of the insect, the rapidity of its spread over large areas, and the suddenness of attack in great numbers—completely blasting in a few

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[a] The present paper is an abstract of a more comprehensive report on the life history and control of the pear thrips to be published later. The recommendations given are based on the results of experiments carried out in the principal centers of infestation since the fall of 1908 to and including the summer of 1910.

[b] Journal of Economic Biology, vol. 4, No. 2, 1909.

days all prospects for a crop of fruit—the control of this pest is a matter of considerable difficulty.

As the insect is each year extending its range of food plants, its capabilities for dissemination are correspondingly increased. There is no reason to believe that the insect will disappear in a few years, but it should be regarded as a permanent pest and at once realized that only the most careful attention each year to necessary control measures will make it possible to continue the profitable culture of deciduous fruit in infested orchards.

Conservative estimates place the damage caused by the pear thrips, in the Santa Clara Valley alone, during the years from 1904 to 1910 at nearly $2,000,000, while the loss for the entire State during this period probably exceeds $3,500,000. It is safe to say that the thrips in the absence of treatment would cause an average yearly loss to the State of over $1,000,000. Also each additional year an increase of several hundred thousand dollars is to be expected, due to the increase of area infested and the greater losses in the areas previously infested.

## CHARACTER OF INJURY.

Injury to the various fruit trees by this species is caused by the feeding of the adults on the developing buds and early blossoms; by the deposition of eggs into the fruit stems, leaf stems, and newly formed fruit, and by the feeding of the larvæ in the blossoms and on the young fruits and foliage. On pears the greater injury is produced by the adults, which often prevent the trees from blooming, while on prunes and cherries the larvæ frequently prevent a crop of fruit from setting after the trees have come into full bloom. Also, the deposition of eggs into the fruit stems of prunes and cherries so weakens the stems that much of the young fruit falls. The feeding injury is not produced by a biting or chewing process. By rasping the tender surfaces in the developing fruit buds and the young fruits with their hardened or chitinous mouthparts, the thrips rupture the skin, causing an exudation of sap which is often followed by more or less fermentation, especially before blooming. The feeding by larvæ on prunes after blooming causes the well-known thrips "scab," while most of the scarred and misshapen pears are caused by the work of the adults.

## LIFE HISTORY.

*Adults.*—The adults (fig. 2) or winged form of the thrips first appear on the trees about the middle of February and emergence

from the ground continues till early April, maximum emergence, however, occurring in late February and early March. Examina-

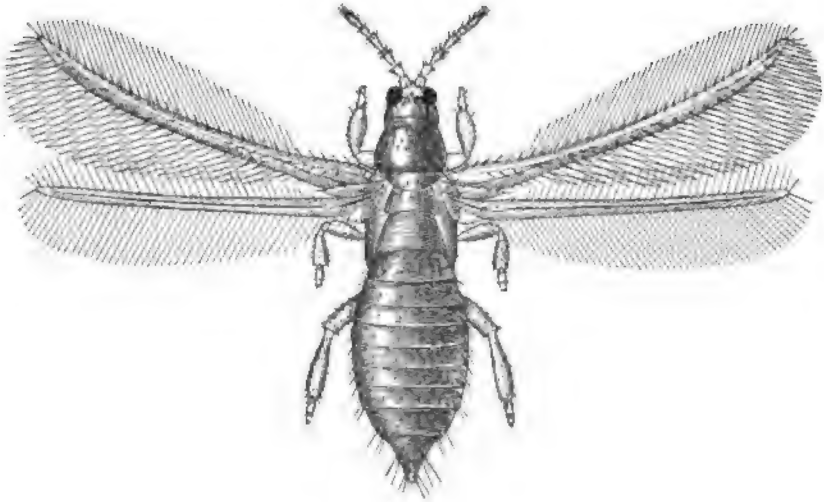


FIG. 2.—The pear thrips (*Euthrips pyri*): Adult, greatly enlarged. (Original.)

tion of the tables of emergence records (Tables I to V) will show the dates of emergence for 1909–10:

**TABLE I.**—*Total daily emergence of thrips from all cages at laboratory, San Jose, Cal., 1909 and 1910.*

| Date. | Number thrips emerging in 1909. | Number thrips emerging in 1910. | Date. | Number thrips emerging in 1909. | Number thrips emerging in 1910. |
|---|---|---|---|---|---|
| Feb. 9 | 0 | 25 | Mar. 8 | 219 | 275 |
| 10 | 0 | 18 | 9 | 776 | 144 |
| 11 | 0 | 16 | 10 | 497 | 100 |
| 12 | 0 | 16 | 11 | 498 | 73 |
| 13 | 0 | 4 | 12 | 338 | 179 |
| 14 | 0 | 88 | 13 | 313 | 45 |
| 15 | 18 | 22 | 14 | 248 | 20 |
| 16 | 0 | 27 | 15 | 279 | 7 |
| 17 | 52 | 34 | 16 | 259 | 4 |
| 18 | 192 | 33 | 17 | 152 | 20 |
| 19 | 192 | 14 | 18 | 42 | 7 |
| 20 | 169 | 23 | 19 | 61 | 2 |
| 21 | 75 | 62 | 20 | 28 | 2 |
| 22 | 119 | 129 | 21 | 2 | .......... |
| 23 | 135 | 375 | 22 | 6 | .......... |
| 24 | 552 | 272 | 23 | 13 | .......... |
| 25 | 459 | 297 | 24 | 3 | .......... |
| 26 | 444 | 455 | 25 | 2 | .......... |
| 27 | 414 | 574 | 26 | 3 | .......... |
| 28 | 781 | 657 | 27 | 7 | .......... |
| Mar. 1 | 781 | 1,975 | 28 | 7 | .......... |
| 2 | 535 | 3,592 | 29 | 0 | .......... |
| 3 | 1,299 | 3,011 | 30 | 2 | .......... |
| 4 | 714 | 4,217 | 31 | 0 | .......... |
| 5 | 508 | 1,402 | Apr. 1 | 3 | .......... |
| 6 | 362 | 1,595 | 2 | 0 | .......... |
| 7 | 438 | 539 | 3 | 1 | .......... |

## Emergence Record for Contra Costa County.

TABLE II.—*Emergence of thrips from cages placed in ground under trees in pear and prune orchards, Walnut Creek, Cal.*

| 1909. | | 1910. | |
|---|---|---|---|
| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
| Feb. 13 | 0 | Feb. 21 | 1 |
| 16 | 20 | 23 | 4 |
| 19 | 37 | 25 | 23 |
| 22 | 30 | 27 | 36 |
| 26 | 110 | Mar. 1 | 56 |
| Mar. 2 | 615 | 3 | 237 |
| 5 | 679 | 5 | 1,170 |
| 10 | 752 | 7 | 2,110 |
| 12 | 273 | 9 | 892 |
| 16 | 65 | 11 | 1,773 |
| 20 | 33 | 13 | 557 |
| 22 | 4 | 15 | 198 |
| 27 | 11 | 17 | 71 |
| | | 19 | 3 |
| | | 21 | 6 |
| | | 27 | 5 |

TABLE III.—*Emergence of thrips from soil samples taken from orchard in November and December and kept in cages at laboratory, Walnut Creek, Cal.*

| 1909. | | 1910. | |
|---|---|---|---|
| Date. | Number of thrips out. | Date. | Number of thrips out. |
| Feb. 12 | 3 | Feb. 18 | 11 |
| 15 | 42 | 20 | 16 |
| 16 | 56 | 22 | 0 |
| 17 | 38 | 24 | 12 |
| 18 | 56 | 26 | 30 |
| 20 | 89 | 28 | 75 |
| 23 | 125 | Mar. 2 | 377 |
| 25 | 185 | 4 | 918 |
| 27 | 246 | 6 | 937 |
| Mar. 1 | 196 | 8 | 165 |
| 4 | 237 | 10 | 114 |
| 7 | 51 | 12 | 47 |
| 10 | 52 | 14 | 0 |
| 14 | 13 | 16 | 4 |
| 19 | 0 | | |
| 22 | 0 | | |

## Emergence Record for Solano County, 1910.

TABLE IV.—*Emergence of thrips from cages placed in ground under trees in orchards, Suisun, Cal.*

| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
|---|---|---|---|
| Feb. 17 | 3 | Feb. 27 | 20 |
| 19 | 0 | Mar. 1 | 47 |
| 21 | 0 | 3 | 121 |
| 23 | 0 | 10 | 484 |
| 25 | 1 | 16 | 1 |

TABLE V.—*Emergence of thrips from samples taken from orchard in November and December and kept in cages at laboratory, Suisun, Cal.*

| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
|---|---|---|---|
| Feb. 16 | 1 | 26 | 11 |
| 17 | 3 | 27 | 14 |
| 18 | 2 | 28 | 41 |
| 19 | 6 | Mar. 1 | 105 |
| 20 | 1 | 2 | 247 |
| 21 | 1 | 3 | 243 |
| 22 | 4 | 7 | 612 |
| 23 | 2 | 12 | 357 |
| 24 | 5 | 16 | 82 |
| 25 | 11 | 19 | 8 |

By the time the fruit buds have swollen sufficiently to separate the bud scales slightly at the tip the adults force their way within, feeding upon the tenderest portions inside the buds. When the thrips are present in sufficient numbers the buds are completely destroyed and the trees fail entirely to bloom.

FIG. 3.—The pear thrips: Eggs, highly magnified. (Original.)

*Eggs.*—As soon as the first leaf surfaces or fruit stems are exposed egg laying usually begins, depending somewhat on the variety of fruit attacked. The first eggs are deposited the last days of February and oviposition continues till near the middle of April, being at its maximum, however, from the 10th of March to the 1st of April. Most of the eggs (fig. 3) are deposited just under the epidermis in the fruit stems, young fruit, and leaf stems. The eggs require from five to seventeen days to hatch, the average time being about eight days.

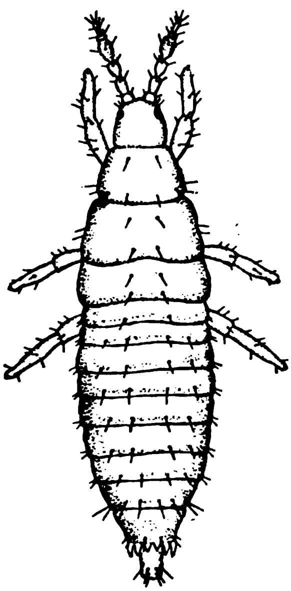


FIG. 4.—The pear thrips: Larva, greatly enlarged. (Original.)

*Larvæ.*—By the time the trees are breaking into full bloom the adults have done most of the damage caused by their feeding, and oviposition is at its height. Many of the earlier appearing adults are dying off and larvæ (fig. 4) are beginning to appear in numbers. The very first larvæ can usually be found about March 20, and are in maximum numbers on the trees, feeding on the small fruit and young foliage, from the first to middle of April. Reaching their full development, the larvæ drop from the trees, of their accord or with falling calyces, or are blown by wind or knocked off by rain. After the

middle of April the number on the trees diminishes rapidly, and by the last of April all the larvæ are off the trees and in the ground. Here they work down into the first 3 or 4 inches of hard soil below the loose surface mulch and construct a tiny cell, where they remain until the following spring.

*Pupæ.*—The larvæ mostly remain as such in these cells till September, when pupation begins, pupæ (fig. 5) being most abundant during October and November. Many adults can be found in the ground in December, and by the 1st of January practically all the thrips are in the adult stage and apparently ready to emerge and go into the trees whenever conditions are right. Broadly speaking, the thrips spend two months of the year in the adult, egg, and larval condition on the trees and the other ten months of the year as larvæ, pupæ, and adults in the ground.

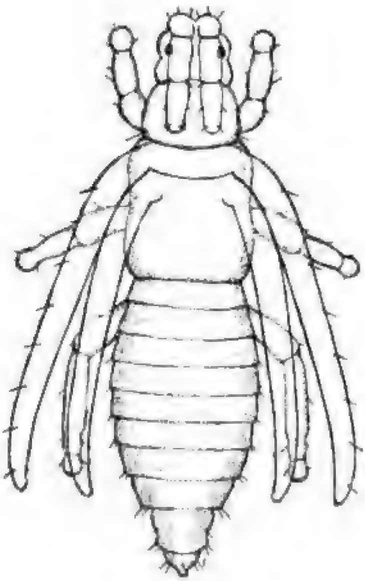


FIG. 5.—The pear thrips: Pupa, greatly enlarged. (Original.)

## CONTROL MEASURES.

The pear thrips is in some respects an unusual insect in that it remains in a dormant or semidormant condition for about ten months of the year. Although on the trees for only two months out of the twelve, it is able in this short time, in the absence of treatment, to completely destroy all prospects of a crop of fruit, in many cases within a very few days. The trees are attacked at the period of bud swelling and blossoming, when they are most susceptible to injury. These minute insects come literally in swarms, and may, if left alone, completely destroy all of the fruit buds of an orchard in four or five days. Many cases have been known where a delay of four or five days in spraying resulted in loss of the entire crop of fruit, and in some cases half of all the buds were killed in three days after the thrips appeared on the trees in great numbers. In view of this condition it is very evident that any means of control must be very thorough and done in the most exacting manner at the proper time.

## EXPERIMENTS IN THRIPS CONTROL.

Many experiments with soil fumigants, fertilizers, and irrigation were made with the hope of killing the thrips while in the ground,

but all of them have proved to be absolutely of no avail, or at most impractical and expensive. In most cases the general vigor and health of the trees were improved by early fall irrigation and by the application of fertilizers.

### CULTIVATION.

Thorough plowing in the fall in prune orchards planted on gravelly and sandy soils gave very helpful results. Success by deep plowing, cross plowing, and harrowing in October and November was fairly general in all experiments tried in Santa Clara County in the fall of 1908 and 1909. This manner of cultivation, when carried out to a depth of from 7 to 9 inches, resulted in killing from 60 to 80 per cent of the thrips present in the soil, but was not a sufficient control, as enough thrips escaped to cause great injury to the buds the following spring.

### SPRAYING.

A long list of insecticides was tried out in spraying experiments, both in the laboratory and by spraying the trees in the spring. All poison sprays had to be abandoned because of the inability to poison the thrips, as both adults and larvæ do not feed in a way to be subject to poisoning. Sticky sprays were difficult to apply and proved ineffective, as they do not retain this quality long and the thrips seem capable of moving around on almost any kind of surface. Dust sprays and preventive sprays had to be abandoned because the dust sprays failed to kill and the rapid swelling of buds and continued appearance of new surface area gave the thrips plenty of feeding ground and exposed places of entrance into the buds. Success with contact sprays seemed more apparent; of these, various caustic sprays, such as caustic-soda and carbolic-acid solutions, gave excellent results in killing the thrips, but were, as a rule, unsafe because of injury to the trees.

Solutions of tobacco extract were very promising, and when used at sufficient strengths killed all the thrips actually reached, but they lacked sufficient penetrating quality to enter the swelling buds, a condition absolutely necessary, especially on pears, as most of the injury is done inside the cluster buds. Mechanical mixtures of various mineral oils and animal-oil soaps were tried and abandoned because of the difficulty of keeping them thoroughly mixed and the resulting injury to the trees caused by free oil separating out. Fish-oil soap emulsions with these various oils gave better results, the raw distillates running from 30° to 40° Baumé being decidedly preferable over either the kerosenes or the heavy crude oils.

A distillate-oil emulsion made according to directions (see pages 8–10) gave better penetration into the swelling pear buds than any other material which has been tried. There was one drawback, however; when this emulsion was used in sufficient strengths to kill all the

thrips present or even a large percentage of them, there was considerable oil injury to the buds. It was found that the weaker emulsions of from 3 to 6 per cent strengths had all the desired penetrating qualities and with little or no injurious effect upon the trees. As the nicotine solutions killed all the thrips present and gave no spray injury this led to a combination of the two in Contra Costa County in the spring of 1909 with most satisfactory results.

A tobacco extract containing 2¾ per cent nicotine, diluted at the rate of 1 to 60 in a 6 per cent distillate-oil emulsion, killed all the thrips touched and penetrated well into the pear cluster buds. The pubescent covering of the individual buds in the cluster, being resistant to water, seemed to act on the dilution in distillate-oil emulsion in much the same manner as the wick upon oil in a lamp. Various other combinations of nicotine solutions with "lime and sulphur solutions" and "lysol solutions" and "soap solutions" were tried extensively, but none proved to be as effective and at the same time as practical as the combination of distillate-oil emulsion and the nicotine solutions.

## DISTILLATE-OIL EMULSION.

*Homemade preparation.*—Because of its cheapness and greater efficiency as a penetrating spray, and therefore a more satisfactory killing agent, growers are strongly advised to make their own emulsions and, preferably, the soap, although the latter can usually be depended on if bought from reliable dealers.

*Directions for making.*—To make soap use this formula or some multiple of same:

| | |
|---|---|
| Water | 6 gallons. |
| Lye (98 per cent) | 2 pounds. |
| Fish oil | 1½ gallons. |

Put the water in a caldron or boiler and add the lye. When the lye is thoroughly dissolved and the water boiling, pour in the fish oil, stirring in the meantime, and boil slowly for two hours. When the soap has boiled sufficiently it should give a ropy effect when stirred and brought up upon the ladle. This formula gives about 40 pounds of moderately firm soap.

Growers are cautioned to buy only genuine fish oil and not a fish-oil compound or a mixture of fish oils and vegetable oils. Herein lies part of the secret of the penetrating efficiency of the distillate emulsions made by using animal-oil soap as the emulsifier. The cost of the soap is $0.0165 per pound made from fish oil at 35 cents a gallon.

The distillate-oil stock emulsion should be made as follows:

Formula:[a]

| | |
|---|---|
| Hot water | 12 gallons. |
| Fish-oil or whale-oil soap | 30 pounds. |
| Distillate oil (raw) 30° to 34° Baumé | 20 gallons. |

[a] For a spray tank of 200 gallons capacity, five times this formula can be made at one time.

Have the water boiling hot when put into the spray tank and add the soap immediately while the agitator is running at a good speed. When the soap is all thoroughly dissolved, pour in the oil slowly, keeping the mixture well agitated while the oil is going into the tank. When all the oil is in and well mixed, pump out through the nozzles at good pressure (not less than 175 pounds) into storage tanks.

No one should attempt to make this stock emulsion without a power spraying machine, as thorough agitation and high pressure are important requisites. Also, care should be used in having measurements reasonably exact, the water boiling hot, and soap thoroughly dissolved, before any oil is put in. This stock emulsion contains approximately 55 per cent oil, and to make a 3 per cent emulsion use 5½ gallons of this stock in each 100-gallon tank. To dilute, first put the stock emulsion in spray tank (have the agitator going), and then add the water, keeping the agitator running all the time. This is important with the commercial preparations as well as with the home-made emulsions. For the combination sprays of oil emulsions and nicotine solutions, the nicotine should be added last, that is, after the oil emulsion has been diluted to the desired strength. These solutions should not be mixed together without first diluting one of them.

This concentrated emulsion will cost the grower about 5 cents per gallon, as most of the various distillates used for spraying cost from 5 to 10 cents a gallon in drum lots.

In the spraying season of 1910 many growers of Contra Costa County experienced great difficulty in making emulsions that would remain emulsified when diluted. Part of this trouble was due to the varying degrees of hardness in the water, but more to the composition of the oil, especially where the treated oils and in some cases ordinary stove distillates were used. Even after these treated oils were emulsified by changing the amount of soap used and treating the water to "soften" it, the result was not satisfactory, as the diluted emulsion from this lacked the essential penetrating quality and had a tendency to collect in large drops rather than to spread out in a thin film.

Experiments conducted thus far indicate that success is more uniformly obtained by using an untreated raw distillate 32° to 34° Baumé with comparatively high flashing point. Some of the treated oils have given good results, but as a whole the untreated raw, straight distillates, comparatively free from naphtha and with a high flashing point, have given far better and more general satisfaction.

Some of the oil companies, particularly in the Bakersfield and Coalinga districts, put out raw short-cut distillates—that is, the first distillate after the naphtha, gasolines, etc., have been removed. This kind of oil when running 32° to 34° Baumé should under all circumstances be given preference. The ordinary stove distillates have not, as a rule, given as good satisfaction, possibly because they

contain too much of the light gaseous oils, which lower the flashing point.

There are several commercial preparations of oil emulsions and miscible oils on the market, but these have not given as satisfactory results against the adult thrips as the homemade preparation, especially on pears, on account of the noticeable lack of penetration into the cluster buds. Besides, all of these commercial preparations are far more expensive. Allowing 25 cents per hour for labor in making the soap and the concentrated homemade emulsion, the commercial preparations cost the grower from 2 to 5 times more than the more efficient homemade preparation.

## COMMERCIAL RESULTS.

During the season of 1909–10 many large-scale experiments and demonstrations were carried out in pear, prune, and cherry orchards to determine more conclusively the effectiveness of this combined spray and to put the treatment on a commercial basis; also, that growers might see for themselves the results of the work and know the monetary gain possible by such control measures as are recommended. The commercial results from some of these experiments are given below:

### PRUNES, SANTA CLARA COUNTY.

The 16-acre prune orchard belonging to Mr. P. Landon, situated in the Willows district, near San Jose, Cal., consists of some of the largest and finest prune trees in the valley. The trees, which are about 25 years old, are planted 20 feet apart and the branches now overlap between the rows. The orchard has very heavy sandy loam and has been well cultivated and usually irrigated twice each year. Thrips became injurious in the year 1906, increasing greatly in 1907, and causing much injury over the entire orchard, so that instead of a normal crop of a hundred or more tons of green (undried) prunes the entire 16 acres produced only 18 tons of green fruit. Injury by the thrips was worse in 1908, the yield that year being only 10 tons of green prunes.

#### DEMONSTRATION FOR 1909.

In the fall of 1908, under direction of the Bureau of Entomology, Mr. Landon plowed and cross plowed this orchard to a depth of 9 inches, with thorough harrowing after each plowing. Thrips were very abundant in the soil, there being sometimes as many as 3,000 to the square foot.

The following table, giving the emergence of adults in spring from samples of soil taken before and after plowing, shows that approximately 70 per cent of the thrips were killed by cultivation:

TABLE VI.—*Number of adult thrips emerging from cages containing samples of soil taken before and after plowing—Landon prune orchard, 1908-9.*

| Plowed and cross plowed. | | | | Before plowing. | |
|---|---|---|---|---|---|
| Cage I. | Cage II. | Cage III. | Cage IV. | Cage V. | Cage VI. |
| 475 | 389 | 607 | 115 | 1,175 | 1,474 |

Average number of thrips per cage before plowing .......................... 1,364
Average number of thrips per cage after plowing and cross plowing ........... 396
Percentage living in treated areas as against the number of thrips living in untreated ground ........................................................per cent.. 30
Approximate percentage killed ........................................do.... 70

In the spring of 1909, 5½ acres of this 16-acre orchard were sprayed three times; twice before blooming, for adults, the first application March 8 and 9, just as cluster buds were spreading, and the second

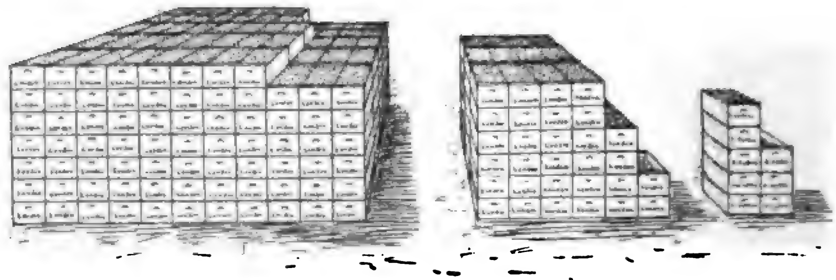
FIG. 6.—Power sprayer at work in Landon prune orchard, 1909. (Original.)

application March 16 and 17, just as the white tips of the petals were beginning to show. The third application or larval treatment was put on April 11 and 12, after most of the petals had fallen. For all sprayings a gasoline-power outfit, with tower platform and three leads of hose, as shown in figure 6, was used, two men spraying from the ground and one from the tower to cover the tops of the trees. The material used was the recommended 3 per cent homemade distillate-

oil emulsion with commercial tobacco extract No. 1, added at the rate of 1–60, and the cost of the three applications was $157.38, the labor required in spraying being three men at $2 per day and one team at $2.50 per day, making a total of $8.50 per day, or a total of $51 for the six days; gasoline for the engine cost $2.40; plowing and cross plowing the previous fall, $26.65, making a total cost of $237.45 for the combined treatment of plowing and spraying the 5⅓ acres, or $44.54 per acre, an average of $0.449 per tree.

The yield from this plat was 45 tons of green prunes, making an average yield of 8.44 tons per acre, or 155.17 pounds per tree. The prunes when dried averaged 54 to the pound, giving a commercial value for the plat of $1,710, or a value of $320.82 per acre, or an average of $2.948 per tree, as the prunes were sold on a 2½-cent basis for dried prunes averaging 80 to a pound.

*Plat II.*—The rest of the orchard, comprising 10⅔ acres, and which only had the plowing and cross plowing in the fall of 1908, at the cost



a b c

FIG. 7.—Diagram showing yield in green prunes per acre upon the sprayed, plowed, and check blocks, Landon prune orchard, 1909: *a*, Sprayed and plowed, 367.93 boxes, value $320.82 per acre; *b*, plowed block, 85.65 boxes, value $74.85 per acre; *c*, check block, 7 boxes, value $6.65 per acre. (Original.)

of $5 per acre, or $0.046 per tree, yielded 21 tons of green prunes, or an average of 1.97 tons per acre, or 36.45 pounds per tree, giving a commercial value of the plat as $798, or a value of $74.85 per acre, averaging $0.692 per tree.

*Plat III, check.*—This plat, embracing 5 acres of the prune orchard belonging to Mr. F. Cottle, and immediately adjoining the Landon orchard and of the same kind of soil and with similar trees in regard to size and previous care, received no treatment for thrips. The total yield was 1,750 pounds of green prunes, or an average yield of 350 pounds per acre, or 3.24 pounds per tree, representing a commercial value of $33.25 for the plat, or an average of $6.65 per acre or $0.06 per tree. The yield and value per acre upon the three plats is shown diagrammatically in figure 7.

The average gain per acre upon Plat I was obtained after adding the total cost of treatment per acre to the value of the crop per acre from the check plat, and subtracting that amount from the value of

the yield per acre upon Plat I. This gave a net gain of $269.53 per acre as returns upon an investment of $44.54, or a gain of about 600 per cent. The gain upon this plat due to the spraying alone was $199.88 per acre, or $1.85 per tree.

Plat II, which received only the plowing and cross plowing, gave, after adding the cost of the treatment to the yield per acre upon the check plat and subtracting the total from the yield per acre upon Plat II, a gain of $63.20 per acre for an investment of $5, or about 1,200 per cent on the investment.

Owing to the lateness of the third application on Plat I, the larvæ caused considerable scabbing on the fruit, and the difference in quality of the fruit from Plat I and Plat II was not as great as would have been the case had the larval application been applied a few days earlier.

### RESULTS, 1910.

During the fall of 1909 part of the orchard was irrigated and the entire 16 acres were plowed to a depth of 8 inches in November. One small block was cross plowed. The entire orchard was harrowed several times after the plowing.

### PLOWING RESULTS.

Soil samples were taken in similar cages as in the previous year and yielded the following results:

| Cage No. | Treatment. | Total number thrips. | Per cent killed. |
|---|---|---|---|
| II | Before plowing | 2,813 | 0 |
| II-a | Plowed once | 353 | 87 |
| IV | Before plowing | 3,379 | 0 |
| IV-a | Plowed once | 1,306 | 61 |
| I | Before plowing | 2,731 | 0 |
| I-a | Plowing and cross-plowing | 27 | 98 |

The average percentage of thrips killed by one plowing was 71 per cent and the average number killed by plowing and cross plowing 98 per cent.

No spraying was done in 1910, except a few trees for other experiments.

*Results.*—All of the trees on the 16 acres came into heavy bloom, but only the 580 trees of Plat I and one block of about 80 trees which was sprayed for larvæ in 1909 set a heavy crop, as many thrips were present in the rest of the orchard. The trees sprayed in 1909 were stronger, and so many of the thrips had been killed by the treatment that the accumulative results showed almost as great a difference in the crop yield for 1910 as was the case in 1909, when the spraying was actually done.

The prunes averaged 57 to the pound, and computations made on the basis of 5 cents for prunes running 80 to the pound. The different yields and values were as follows:

*Plat I—Demonstration block of 1909, consisting of 580 trees.*—This block yielded 35 tons 212 pounds of green prunes, worth $2,109.87 for 580 trees, or $3.63 per tree or $392.04 an acre.

*Plat II—Sprayed for larvæ in 1909, 80 trees.*—This block yielded 2 tons 676 pounds of green prunes, worth $140.51 for 80 trees, or $1.99 per tree or $214.92 per acre. (This was part of Plat II in 1909.)

*Plat III—Remainder of orchard, consisting of 10 acres, not sprayed in 1909.*—This block yielded 7½ tons of green prunes worth $450.75 for 1,080 trees or 10 acres, making $0.417 a tree or $45.075 an acre.

An examination of the above statement of yields and values shows that great headway can be made the first year in eliminating the thrips injury from an orchard by thorough spraying and that a considerable benefit extends into the second year.

### Demonstrations for 1910.

The 6½-acre prune orchard belonging to Mr. H. Curry was plowed and cross-plowed in November, 1909, to a depth of 11 inches and harrowed after each plowing. The block was then sown to barley for a cover crop which made a good growth and was at spraying time nearly 3 feet high.

Examination of two samples of soil 17 by 17 inches square, taken before plowing, and two of the same size taken after plowing, showed that approximately 61 per cent of the thrips were killed.

*Plat A.*—In addition to the fall plowing, this block of 300 trees received three applications of commercial tobacco extract No. 1 combined at the rate of 1 to 66 with 3 per cent homemade distillate-oil emulsion. The first spraying was applied March 7, just as the cluster buds were spreading. The second for adult thrips was made March 17, as the tips of the petals were showing. The third application, which was for the larvæ, was made April 6, after most of the petals had fallen. In all of the spraying an effort was made to direct the spray into the end of each bud and to drench the trees thoroughly.

*Plat B.*—This plat, consisting of 98 trees, received the cultivation, but no spraying.

*Results.*—The first application was made too late to obtain best results, and a large number of buds was so far advanced that it was difficult to reach all of the thrips. A series of counts showed that all of the exposed thrips were killed and about 30 per cent of those within the buds. The second application killed practically all the thrips left on the trees (over 90 per cent), as the bud clusters were spreading at this time. A fair portion of the blossoms set fruit on the

sprayed block and some on the plowed block, but the fruit on the latter continued to drop until picking time. The yield upon the various plats is shown diagrammatically in figure 8, and was as follows:

Plat A yielded 16,254 pounds of green prunes, or 8,127 pounds of dried prunes, from the 300 trees. This made an average yield of 5,849.92 pounds of green prunes per acre, or 54.166 pounds per tree.

Plat B yielded 1,032 pounds of green prunes or 516 pounds of dried prunes from the 98 trees, or an average of 1,138.32 pounds per acre, or 10.54 pounds of green prunes per tree.

Plat C, consisting of 10 acres, was left untreated to serve as a check for comparison, and yielded 860 pounds of green prunes, or 430 pounds of dried prunes, for the 1,080 trees. This gives an average yield of 86.4 pounds per acre, or 0.8 pound of green prunes per tree.

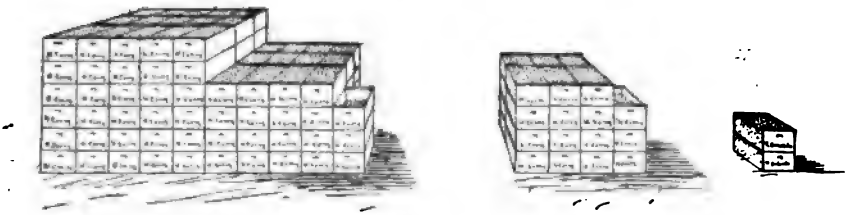



FIG. 8.—Diagram showing yield per acre in green prunes, Curry orchard, 1910: *a*, Sprayed and plowed, 136.08 boxes, value $190.08 per acre; *b*, plowed block, 26.46 boxes, value $34.02 per acre; *c*, check block, 2 boxes, value $2.59 per acre. (Original.)

*Scabbiness.*—An examination and count was made of all the fruit from 5 trees on the sprayed block and from 5 trees in the unsprayed block, giving the following results:

| Plat. | Total number prunes. | Number clean. | Number scabby. | Per cent free from scab. |
|---|---|---|---|---|
| Sprayed block | 10,139 | 9,831 | 308 | 96 |
| Unsprayed block | 826 | 0 | 826 | 0 |

It will be seen from the above table that the sprayed fruit was practically free from scab (the 4 per cent that was scabby being only very slightly marked), while the unsprayed fruit was all badly scabbed.

*Size of fruit.*—Comparisons of the sprayed and unsprayed fruit when dried showed the former to average 50 prunes to the pound and the unsprayed 60 to the pound, making a difference of $10 a ton, which would pay nearly half the cost of the spraying.

*Value of the crop.*—As all of the values of the prune yields for 1910 have been figured on a 5-cent basis for prunes averaging 80 to the pound dried, this basis is here employed, although the crop was sold for more than the above quotation and premiums were given for the large size and quality of the fruit.

Plat A, which produced 16,254 pounds of green prunes from 300 trees, gave a crop value of $528.255, or $1.7608 a tree, or $190.08 an acre.

Plat B, which yielded 1,032 pounds of green prunes from 98 trees, gave a crop value of $30.96, or $0.315 a tree, or $34.02 an acre.

Plat C, which yielded 860 pounds of green prunes from 1,080 trees, gave a crop value of $25.80, or $0.024 a tree, or $2.592 an acre.

*Cost of spraying.*—As 3,800 gallons of diluted spray material were used for all three sprayings upon Plat A, the total cost at $0.01625 per diluted gallon would be $61.75. The labor and gasoline cost 2 cents a tree, each application, for the 300 trees, or a total of $18. The total cost of the spraying was $79.75, or $0.265 a tree, or $28.78 an acre for the three applications.

*Gain due to spraying.*—The gain due to the spraying would be obtained by adding the value of the crop per tree on Plat B to the cost of the spraying and subtracting the product from the value of the crop per tree of Plat A. This gives a gain due to the spraying of $1.18 per tree, or $127.44 an acre.

### Other Demonstrations.

In cooperation with or working under the advice of the Bureau of Entomology, several fruit growers in Santa Clara, Contra Costa, Solano, and Sacramento counties during 1910 gave thorough treatment to portions of their orchards and left similarly infested areas untreated without any protection from thrips injury. Many of these demonstrations were highly successful, but for lack of space only two of these are recorded herein in some detail. These results show very conclusively what can be done by the individual growers if the right material is properly applied in time to kill the thrips before the buds have been destroyed, and that the treatment will increase the yield and value of the crop, frequently paying several hundred per cent on the investment.

#### PEARS, CONTRA COSTA COUNTY.

An orchard consisting of about 5½ acres of Bartlett pears belonging to John Swett & Sons, in the Alhambra Valley, near Martinez, Cal., had been badly damaged by thrips for three years, causing almost total failure of crop.

In the spring of 1910 Mr. Frank T. Swett had 550 of the trees sprayed twice for adults, and a portion of these received a third application or larval treatment. All spraying consisted of the recommended material (commercial tobacco extract No. 1 diluted 1 part to 66 in 3 per cent homemade distillate-oil emulsion) put on the trees with good pressure, using gasoline-power outfit with 8-foot tower, thus enabling one man to cover thoroughly the tops of the trees and

drench all buds pointing upward which could not be properly sprayed by the men on the ground.

Four trees in one side of this orchard, same variety, same age and size, and all other conditions the same, were left unsprayed.

*Results.*—Without a single exception all of the 550 sprayed trees came uniformly into full bloom, while the trees left unsprayed showed only very few scattering blossoms and these badly injured. Figure 9

FIG. 9.—Swett pear orchard at time of blooming. Sprayed trees. (After Swett.)

shows the condition of a sprayed tree at blossoming time. The 550 sprayed trees gave a yield of 1,700 boxes of No. 1 pears and 150 boxes of No. 2 pears. The No. 1 pears, at an average net price of 80 cents per box, gives $1,360, and the 150 boxes of No. 2 pears, at 50 cents per box, gives $75, making a total of $1,435, the value of the crop from 550 sprayed trees, or practically $2.60 per tree.

Figure 10 shows an unsprayed tree at blossoming time. The unsprayed trees gave a yield of less than one-fourth box per tree, all of which was scarred, misshapen, and unmerchantable; but counting them as No. 2 pears, at 50 cents per box, gives a return of about 12½ cents per tree.

According to Mr. Swett, the spraying, including material, labor, and all expenses connected with the operation, cost less than 25 cents

FIG. 10.—Swett pear orchard at time of blooming. Unsprayed trees, sprayed portion of orchard in background. (After Swett.)

per tree for the 550 trees. This, plus the value of the crop (12½ cents) from the check trees, gives 37½ cents. Subtracting this from the $2.60, value of the crop per tree in the sprayed block, leaves a net gain of $2.125 per tree, or approximately $225 per acre, or a return of over 900 per cent on the investment.

In the letter giving the results upon which these itemized figures are based, Mr. Swett continues:

The results from spraying on prune trees were very marked. Owing to cross limbs we could not use the tower in spraying the prune orchard. The crop was protected only up to the distance from the ground that could be reached by the spray rods. We wet the tops of the trees as best we could, but could not drive the spray into the bud and flower clusters directly from the nozzles. Anyone can tell where the rods reached, for above the line there is no crop, and below that line the limbs mostly have to be propped.

### CHERRIES, SACRAMENTO COUNTY.

A good demonstration showing the possibility of control and the commercial advantage by spraying cherries was given by Mr. T. W. Dean, near Courtland, Cal. Mr. Dean has about 1½ acres or 180 trees in bearing, which were sprayed upon an average four times in the spring of 1910 (some of the trees sprayed five times and the remainder only three times). The cost of the spraying was approximately \$90, or 50 cents per tree. Mr. Dean shipped 1,362 boxes of cherries from the 180 trees, or 7.56 boxes per tree, which, at a net value of \$1.196 per box, gives a return of \$1,619.95, or \$8.99 per tree.

Sixty-five trees belonging to Mr. I. G. Doty and immediately adjoining the above orchard were not sprayed. The 65 trees gave a yield of 43 boxes, averaging practically two-thirds of a box per tree, or a cash value of \$0.798 per tree. Adding this to the cost of spraying, 50 cents per tree, gives \$1.30 as the amount to be deducted from the value of the crop per tree in the sprayed orchard. The difference is \$7.49 per tree, or approximately \$898.80 per acre, the net gain due to spraying paying over 1,400 per cent on the investment.

## RECOMMENDATIONS.

Spraying is by far the most satisfactory means for controlling the pear thrips on all classes of deciduous fruit trees in California. However, to spray successfully involves an entirely different conception of the operation than as ordinarily practiced against other orchard insects. Only the most efficient spray materials should be used, namely, the combination of distillate-oil emulsion and tobacco extract or distillate-oil emulsion and nicotine solutions. The spraying must be thoroughly done and put on the trees when the thrips appear in numbers, not waiting till many buds have been destroyed. It is strongly advised to use power machines, and growers are urged to use them for all the spraying, and to have a tower platform elevated over the tank so that one man can thoroughly drench the tops of the trees. Figures 6 and 11 show two good types of power outfits at work. It is absolutely necessary to use high pressure—from 150 to 200 pounds—and only angle nozzles should be employed, and these

must be held close to the bud clusters to *force the spray directly into the ends of the buds.* This is absolutely necessary to secure good penetration and get satisfactory results. Plenty of material—3 to 5 gallons per tree for pears, depending on the size of the tree—should be used; more liquid is required for large prune trees; large cherry trees may require 7 to 8 gallons per tree for satisfactory results. Only two rows should be sprayed at a time, using three men, one on the tower to spray the tops of the trees, thus reaching all buds pointing upward, and two men on the ground (one to each row) to spray the lower buds and those pointing downward or laterally.

FIG. 11.—Power outfit ready for use in spraying experiments in pear orchards, Contra Costa County, Cal., 1910. (Original.)

TIMING THE APPLICATIONS.

The spraying must be done on time, and for best results all the trees should be treated within a few days. During the season of 1910 more of the failure to get satisfactory results was due to lateness of application than to any other one cause. Thrips were in the trees and in great numbers before many of the growers purchased their spraying supplies, and in many cases half the buds were entirely destroyed and the others badly injured before the trees had been given even the first application. The grower should have everything in readiness, all materials on hand, concentrated emulsion made up, and spray machinery in perfect working order by the first of March and have all other orchard work in such shape that when the thrips appear in numbers

the spraying may be done at once and before the buds have been seriously injured by the feeding of the adults. The grower should have enough spray machines to cover the orchard quickly. At least one good power outfit is necessary for every 30 acres of orchard.

### SCHEDULE OF APPLICATIONS.

In badly infested orchards three applications are necessary the first year for controlling the pear thrips. Two of these sprayings should be directed against the adults and one against the larvæ, and to obtain satisfactory results must be timed properly.

*First application.*—The first spraying should come as soon as the thrips can be found on the trees in numbers. This will usually be the first two or three days of March, just as the earliest buds are separating slightly at the tips. In figures 12, 13, and 14 are shown photographs of the more advanced buds of Bartlett pear, Imperial and French prunes, and Black Tartarian cherry, which were taken at time of first application.

Fig. 12.—Bartlett pear cluster buds showing stage of earliest buds at time of first spraying against thrips. (Original.)

*Second application.*—The second spraying, which is also for adults, should come from four to ten days after the first, depending somewhat on variety of fruit, stage of bud development, and rapidity of emergence of thrips from the ground. On pears this will usually be just as the earliest cluster buds are spreading, and on prunes and cherries when the tips of the petals first begin to show.

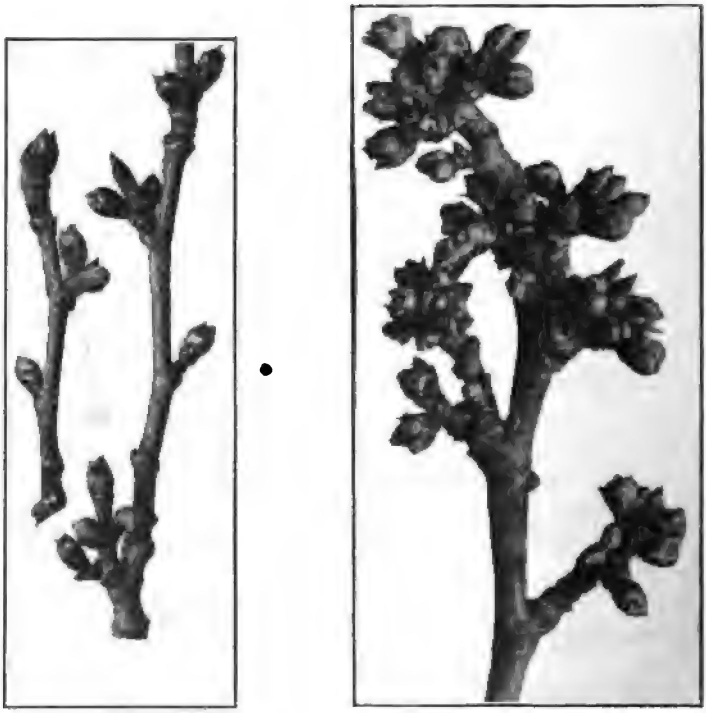
Both of these applications are important and necessary to insure the production of a good crop of uninjured blossoms. The nozzles should be held close to the bud clusters and the spray directed into the ends of the buds. This makes it necessary that the spraying be done mostly from above.

*Third application.*—The third spraying is for larvæ and properly comes just as most of the petals are falling from the trees, depending somewhat upon the variety of fruit. In any case the small, white, active larvæ can be easily seen, and when they first become abundant spraying should be done. In this larval spraying on cherries and prunes where there is a large amount of leaf surface exposed, the

spray should be directed first against the underside of the leaves, beginning with the lowest branches and spraying upward. Most of the larvæ are feeding on the under surface of the leaves, and spraying the upper surface first would serve to knock the larvæ from the trees without their coming into contact with the spray. Angle nozzles of the type shown in figure 15, giving coarse, penetrating spray, should be used for all applications.

### MATERIALS TO USE.

The combination of 3 per cent homemade distillate-oil emulsion, made from raw distillate, 32° to 34° Baumé, and the nicotine solutions,



a b

FIG. 13.—*a*, French prune buds; *b*, Imperial prune buds; showing stage of earliest buds at time of first application against thrips. (Original.)

is given preference over all other sprays used so far. To dilute, measure out 5½ gallons of the stock emulsion for each 100-gallon spray tank, or 11 gallons for a 200-gallon tank; start the engine; pour the stock emulsion into the spray tank, and while the agitator is running, add the water to fill up the tank, putting in the strong nicotine solution last and after the stock emulsion has been diluted. For spraying in the interior counties add to this dilute oil-emulsion

commercial tobacco extract No. 1, which is a dark, almost viscous liquid containing 2.75 per cent nicotine, at the rate of 1 to 75; or tobacco extract No. 2, which is a light-colored liquid containing 40 per cent of almost nonvolatile nicotine at the rate of 1 to 1,500, or a fraction more than a pint to a 200-gallon tank. This form of the nicotine has been highly efficient and will in all probability be more satisfactory than the former. By reason of its greater concentration the handling and transportation charges will be much less; also, the nicotine contained in this preparation is much less volatile, thus allowing the use of a smaller amount of actual nicotine in the dilution, as it remains an active killing agent for a longer time on the trees.

FIG. 14.—Buds of Black Tartarian cherry at time of first application against thrips. About one-half natural size. (Original.)

In Santa Clara County greater dilutions than these have been found to be satisfactory, due most likely to different climatic conditions, evaporation there being much less at this time than in the interior counties where the atmosphere is drier. Growers in the Santa Clara Valley are advised to use the 3 per cent distillate-oil emulsion, with tobacco extract No. 1 added at the rate of 1 to 100 or tobacco extract No. 2 at the rate of 1 to 2,000. These recommendations hold for all thrips sprayings, for both adults and larvæ and on all varieties of deciduous fruits attacked by the pear thrips. No orchards should be sprayed, however, when the trees are in full bloom. All spraying for adults should be done before the blossoms appear and spraying for larvæ after a large proportion of the petals have fallen.

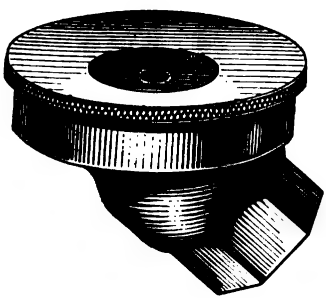


FIG. 15.—Angle nozzle of the large chamber type used in spraying experiments. (Original.)

In the prune orchards of Santa Clara Valley deep fall plowing and cross-plowing has proved a valuable and profitable aid in controlling the thrips. Those who can do so are strongly advised to irrigate their orchards in September or October, and when the soil is in proper condition plow with disk plows to a depth of 7 or

8 inches and harrow, then cross plow 8 to 9 inches deep and harrow again. All plowing should be done during the months of October and November. During this season the thrips are passing through the tender pupal stage and are more easily killed by mechanical means than at any other season of the year.

Plowing has not proved satisfactory as even a partial means of controlling the thrips in the pear orchards of the interior counties. This is due, perhaps, to several conditions, one of which is the different type of soil, and another, the fact that the area of soil infested with thrips around pear trees is very much less than around prune trees, the branches of which spread farther, covering a greater surface of ground. The larvæ in leaving the trees fall to the ground directly from the foliage and young fruit, rather than crawl down the trunks of the trees; hence in a prune orchard they are more widely distributed throughout the soil between the trees and can be reached by the plows, while in a pear orchard most of the larvæ in the ground are close around the base of the trees.

## SUMMARY.

The pear thrips can be controlled by thorough spraying on any variety of the deciduous fruits grown in the infested areas of California.

The sprayings necessary to control the thrips are expensive, but the outlay of money and labor gives large returns. Many experiments in spraying have given net returns of from $100 to $600 per acre more than was secured from adjoining untreated areas.

The thrips work rapidly and may destroy all prospects of a crop in less than a week's time. Spraying, to be successful, must be done thoroughly and at the time to kill the thrips before the fruit buds have been destroyed.

Those who can do so successfully are advised to irrigate and plow in the fall. This is to be followed by thorough spraying the following spring.

When the thrips begin to appear on the trees in numbers, spraying should be done thoroughly, using high pressure, holding nozzles close to buds, and *directing the spray directly into the ends of the buds, and not against the sides.*

Growers should not attempt to spray too many trees with one machine. More profitable returns will be gained by spraying half of the orchard thoroughly and at the proper times than by spraying all the orchard poorly one time. Results of the work in 1909 and 1910 show conclusively that one application is not sufficient when the thrips are abundant.

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L. O. HOWARD, Entomologist and Chief of Bureau.

# THE PERIODICAL CICADA IN 1911.

BY

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*Entomologist and Assistant Chief of Bureau.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE PERIODICAL CICADA IN 1911.

(*Tibicen septendecim* L.)

By C. L. MARLATT,
*Entomologist and Assistant Chief of Bureau.*

### INTRODUCTION.

Two important broods of the periodical cicada (fig. 1) will appear this year. One of these belongs to the 17-year race and extends from New York southward into North Carolina, in general lying east of the Allegheny Mountains. The other is one of the largest brood of the southern, or 13-year, race and covers the lower half of the Mississippi Valley. Both of these broods have been very well studied in past years, and their distribution has been satisfactorily and in the main probably accurately determined. The approaching reappearance, however, of these broods of the cicada is already leading to inquiries, and this circular is issued to meet such inquiries, and also for the purpose of securing reports of occurrence to add to the present knowledge of the distribution of these broods.

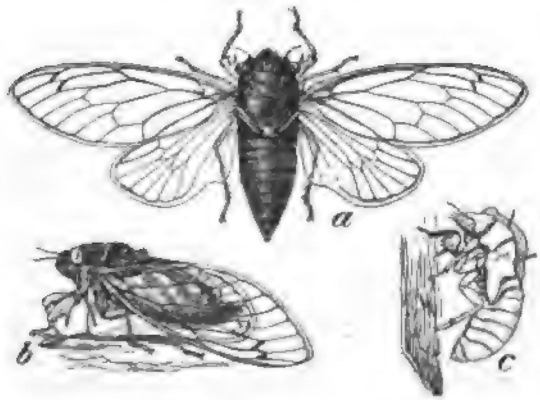

FIG. 1.—The periodical cicada (*Tibicen septendecim*): *a*, Adult; *b*, same, side view; *c*, shed pupal skin. (Author's illustration.)

### 17-YEAR BROOD II.

This brood, in the main, occupies territory immediately east of Brood I—a scattering brood appearing in 1910. Its exact range is shown on the accompanying map (fig. 2), the black dots indicating records by counties only of the appearance of the insect in former years at the regular 17-year intervals. In many cases we have numer-

ous records for individual counties, but these are represented on the map by a single dot. This is one of the best recorded broods, since its almost exclusively eastern range brings it into the immediate vicinity of the larger towns and more populated districts of the Atlantic seaboard. It has been reported in Connecticut regularly every 17 years since 1724 and in New Jersey since 1775, and almost equally long records of it in other States have been made. At its last appearance in 1894 it was carefully studied, to determine distribution, for New Jersey by

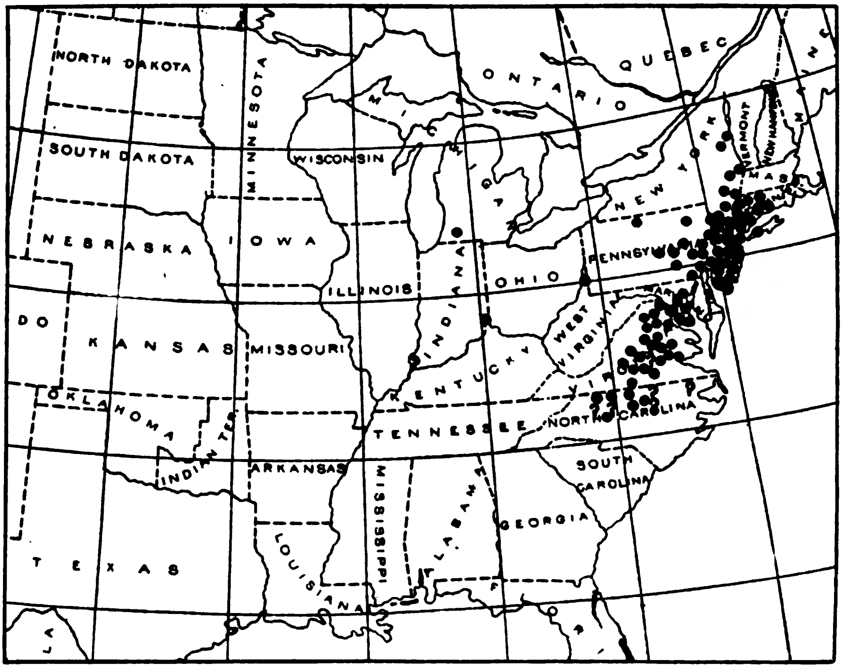


FIG. 2.—Map showing distribution of 17-year Brood II, 1911.

Dr. John B. Smith, for New York by Dr. J. A. Lintner, and for the other States covered by its range by this bureau, with the aid of State entomologists and local observers. Some of the southern records obtained in 1894 are doubtful, and this applies especially to localities in North Carolina, because of the appearance the same year of Brood XIX of the 13-year race, which, in North Carolina, may touch or overlap this 17-year brood. It is therefore very desirable that all observers in South Carolina report occurrences this year of the periodical cicada to clear up these doubtful records.

The distribution, as listed below, is based upon all of the available records:

*Connecticut.*—Fairfield, Hartford, Litchfield, Middlesex, New Haven.
*District of Columbia.*—Throughout.
*Indiana.*—Dearborn, Posey (?).
*Maryland.*—Anne Arundel, Calvert, Charles, Prince Georges, St. Marys.

*Michigan.*—Kalamazoo.

*New Jersey.*—Entire State.

*New York.*—Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Saratoga, Ulster, Washington, Westchester, and on Staten Island and Long Island.

*North Carolina.*—Bertie (?), Davie (?), Forsyth (?), Guilford, Orange, Rockingham, Rowan, Stokes, Surry, Wake (?), Warren (?), Yadkin (?).

*Pennsylvania.*—Berks, Bucks, Chester, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Montgomery, Northampton, Philadelphia, Pike, Potter, Schuylkill, Wyoming.

*Virginia.*—Albemarle, Alexandria, Amherst, Appomattox, Bedford, Buckingham, Campbell, Caroline, Charlotte, Culpeper, Fairfax, Fauquier, Fluvanna, Goochland, Hanover, Henrico, James City, Loudoun, Louisa, Lunenburg, Madison, Page, Pittsylvania, Powhatan, Prince Edward, Rappahannock, Spottsylvania, Stafford.

*West Virginia.*—Brooke (?).

## 13-YEAR BROOD XXIII.

As already indicated, this is one of the largest of the 13-year broods, dividing this honor with Brood XIX. Brood XXIII, appearing this

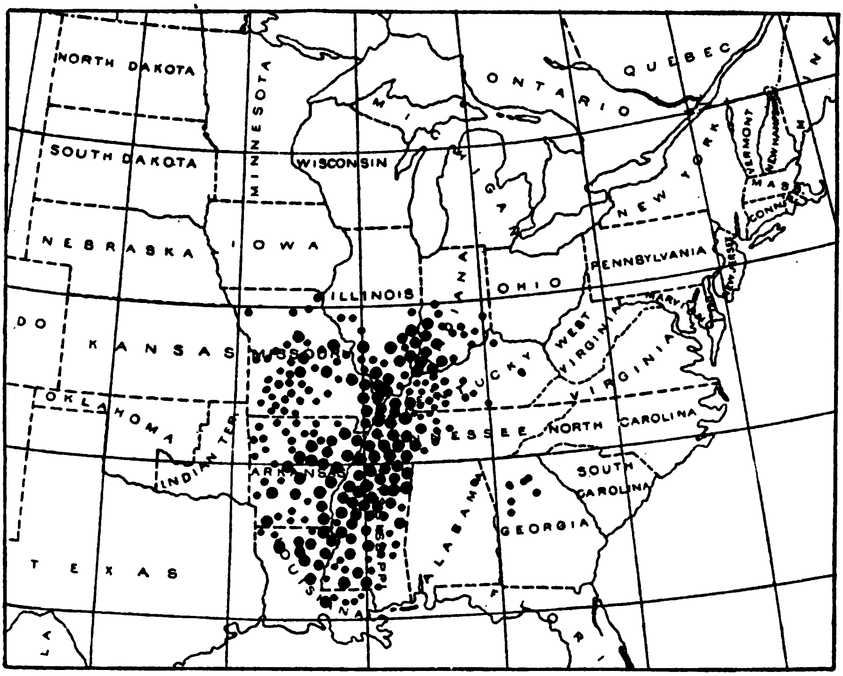


FIG. 3.—Map showing distribution of 13-year Brood XXIII, 1911.

year, occupies the Mississippi Valley from northern Missouri and southern Illinois to Louisiana, covering particularly the States bordering on the Mississippi River. Its distribution is indicated on the accompanying map (fig. 3) by black dots representing counties merely, but the abundance of the distribution of the insect is indicated

somewhat by the size of the dots, the small dots indicating scattering or occasional colonies and the large dots abundant and general occurrence of the insect.

This brood was given very careful study by the writer in 1898, and several thousand replies were received in response to circulars distributed throughout the region where this brood was supposed to occur, and also covering a much wider surrounding region. Local investigations were undertaken at this time by the official entomologists of the several States, notably Forbes (Illinois), Garman (Kentucky), and Stedman (Missouri). These State reports confirmed and supplemented the records obtained by this bureau, and are the basis of the records given below and of the map.

Nearly all the reports for 1908 indicated the occurrence of the insect in enormous numbers. Unfortunately, however, there was some doubt as to the correct reference of some of the localities in Illinois and Indiana, and perhaps northern Missouri, where there was an overlapping of this brood (XXIII of the 13-year race) with Brood VI of the 17-year race. In the case of the records, however, assigned to the 13-year Brood XXIII in the States mentioned, wherever there was a question as to the accuracy of the reference to the proper brood a query follows the county in the list of States and counties given below. It is very desirable, therefore, in obtaining records of this year to note particularly the occurrence of the insect in northern Missouri, southern Illinois, and Indiana, to clear up any doubt which may be attached to the records from these districts.

In the list of counties given below those followed by a star (*) indicate counties in which the cicada occurred in one or more dense swarms, in most instances many reports being received from the same county. In the unstarred counties the cicada was observed in few or scattering numbers, or at least was not abundant. The counties in italics duplicate old records. The counties lacking confirmation by the records of 1898 are inclosed in parentheses and included with the others.

The State and county records follow:

*Alabama.*—Etowah.

*Arkansas.*—*Arkansas,** Ashley, Calhoun, Carroll, *Chicot,** Clark,* *Columbia,* Craighead,* Crawford, Crittenden,* *Cross,** *Desha,** (Franklin), Fulton, Garland, Hot Spring, Howard, (Izard), (Jackson), *Jefferson,** Lafayette,* Lee,* Lincoln, Logan, Lonoke,* *Marion,* *Mississippi,** Monroe,* Newton, *Phillips,** Pike, Poinsett,* *Prairie,** *Pulaski,* Randolph, St. Francis,* *Saline,** (Searcy), Sebastian, Sharp, Union, Van Buren, Washington, Woodruff.*

*Georgia.*—(Cobb), (Coweta), (Dekalb), (Gwinnett), (Meriwether), (Newton).[1]

*Illinois.*—*Alexander,** Crawford,* Edgar, Edwards,* Gallatin, Hardin,* *Jackson,** Jasper,* Jefferson, Johnson, Lawrence,* *Macoupin,* *Madison,** Marion,* *Perry,** *Pike,* Pulaski,* *Randolph,* Richland, St. Clair, *Scott,* *Union,** Wabash,* *Washington,* Wayne,* White, Williamson.*

[1] None of these localities, all of which were queried, was confirmed in 1898, and the record of this brood in Georgia is undoubtedly erroneous.

*Indiana*.—Bartholomew, Daviess,* Fayette, Floyd, Gibson,* Jackson, Jennings, Knox,* Montgomery, Owen, *Posey*,* Putnam, Ripley, Spencer, Sullivan,* Vanderburg,* Vigo,* Warrick.*

*Kentucky*.—Ballard,* (Barren?), Butler, Caldwell, Calloway, Carlisle,* Christian, Clinton, Crittenden, Daviess, Fulton,* Grant, *Graves*,* Green, Hancock, Hardin, Hickman,* Hopkins, Livingston, Lyon, McCracken, McLean, Marshall, Muhlenberg, Ohio, Todd, *Trigg*,* Union, Webster, Wolfe.*

*Louisiana*.—Bienville,* (Bossier), *Caldwell*,* Claiborne, Concordia,* *East Carroll*,* East Feliciana, *Franklin*,* *Madison*,* *Morehouse*, Ouachita,* Pointe Coupee,* (Red River), *Richland*,* St. Helena, Tangipahoa, Tensas,* (Washington), *West Carroll*.*

*Mississippi*.—Adams, *Alcorn*,* *Amite*,* Attala,* Benton,* *Bolivar*,* *Calhoun*,* *Carroll*,* *Claiborne*, *Coahoma*,* *Copiah*,* *De Soto*,* *Franklin*, Grenada,* *Hinds*,* Holmes,* (Issaquena), Itawamba, (Jasper), Jefferson, *Lafayette*,* *Lawrence*, Leake, Lee,* Leflore,* *Lincoln*,* Lowndes, *Madison*,* Marion, *Marshall*,* *Montgomery*,* Neshoba, *Newton*, Oktibbeha,* *Panola*,* Pike,* Pontotoc,* Prentiss,* *Quitman*,* *Rankin*,* (Scott), *Simpson*, *Smith*, Tallahatchie,* *Tate*,* Tippah, (Tishomingo), Tunica,* Union,* Warren,* Washington,* *Webster*,* Yalobusha,* Yazoo.*

*Missouri*.—*Audrain*,* Barry, Benton, *Boone*, Callaway, Camden, *Cape Girardeau*,* Cedar, *Christian*, Clark (?), Clinton, Cole, Cooper, *Dade*, *Dallas*, Dent, *Douglas*, *Gasconade*, *Greene*, *Hickory*, Howell, Iron, *Jefferson*, *Johnson*, *Knox*, (Lawrence), Linn, Maries,* Miller, Morgan, *New Madrid*,* *Osage*,* Ozark, Pemiscot,* *Perry*,* *Pettis*, Phelps, *Polk*, Pulaski, Reynolds (?), *St. Charles*,* St. Clair, St. Francois, *St. Louis*, *Scott*,* *Taney*, *Texas*, *Warren*, *Washington*,* *Webster*.

*Ohio*.—Hamilton.

*Tennessee*.—*Benton*,* *Carroll*,* *Chester*,* *Crockett*, (Davidson), *Decatur*,* *Dickson*,* *Dyer*,* *Fayette*,* *Gibson*,* *Hardeman*,* Hardin,* *Haywood*, *Henderson*,* Henry,* *Humphreys*,* *Lake*,* *Lauderdale*,* Lewis, *McNairy*,* *Madison*,* (Maury), Montgomery, *Obion*,* Perry,* (Robertson), Rutherford, *Shelby*,* Stewart, *Tipton*,* Wayne,* *Weakley*,* Williamson.


FIG. 4.—Egg punctures of the periodical cicada: *a*, Twig showing recent punctures, from front and side, and illustrating manner of breaking; *b*, twig showing older punctures, with retraction of bark, and more fully displaying the arrangement of fibers. Natural size. (After Riley.)

## GENERAL CONSIDERATIONS.

The periodical cicada is so well known that a general account of it in this place is unnecessary. When it appears in great numbers it naturally causes considerable alarm and arouses fears for the safety of shade trees and orchards. The actual damage, however, is usually slight, except in the case of newly planted orchards, and even here, by vigorous pruning back after the cicada has disappeared, much of the injury caused by the egg punctures (fig. 4) can be obviated.

Ordinary repellent substances, such as kerosene emulsion or carbolic-acid solutions, seem to have very little effect in preventing the oviposition of these insects. Some more recent experience, how-

ever, indicates that trees thoroughly sprayed with Bordeaux mixture or lime wash are apt to be avoided by the cicada, especially if there are other trees or woods in the neighborhood on which they can oviposit. The most reliable means of protecting nurseries and young orchards is by collecting the insects in bags or umbrellas from the trees in early morning or late evening, when they are somewhat torpid. Such collections should be undertaken at the first appearance of the cicada and repeated each day.

Approved.

James Wilson,

*Secretary of Agriculture.*

Washington, D. C., *January 3, 1911.*

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Issued March 7, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—CIRCULAR No. 134.

L. O. HOWARD, Entomologist and Chief of Bureau.

# DAMAGE TO TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

BY

T. E. SNYDER,

*Agent and Expert.*

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1911

77538°—11

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Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

### Forest Insect Investigations.

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H. E. Burke, J. L. Webb, Josef Brunner, S. A. Rohwer, T. E. Snyder, W. D. Edmonston, W. B. Turner, *agents and experts.*
Mary E. Faunce, *preparator.*
William Middleton, Mary C. Johnson, *student assistants.*

CIRCULAR No. 134. Issued March 7, 1911.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# DAMAGE TO TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.[1]

By T. E. SNYDER,
*Agent and Expert.*

It has recently been determined through special investigations conducted by the Bureau of Entomology, in cooperation with telephone and telegraph companies, that serious and extensive damage is being done in certain localities to standing poles by wood-boring insects. The object of this circular is to give information on the principal as well as other types of insect injury to poles, so that line inspectors may distinguish the various types and determine and report on the character and extent of the damage.

## CHARACTER OF THE INJURY.

The principal injury to the poles consists in large mines in the wood near the line of contact with the ground, necessitating the frequent resetting or even the replacement of the damaged poles. These irregular mines (fig. 1) run both transversely and longitudinally throughout the heartwood, and are sometimes 7 inches long, but vary in length. This injury is usually in the outer layers of the wood for a distance of from 2 to 3 feet below and sometimes from 1 to 2 feet above the line of contact of the pole with the surface of the ground. The greatest damage is to that area just below and just above the surface of the ground; here the conditions of air and moisture are most favorable. The mines, often very close together, completely honeycomb the wood in a zone from 3 to 4 inches in from the exterior of the poles (fig. 3); this so weakens the poles that they break off close to the surface of the ground. The basal 2 feet is

[1] Revised extracts from Bulletin 94, Part I, Bureau of Entomology, U. S. Department of Agriculture, 1910.

*a* *b*

Fig. 1.—Work of the pole borer (*Parandra brunnea* Fab.) in an untreated chestnut pole: *a*, Gallery of the pole borer, showing pupal chamber with the entrance plugged with excelsior-like wood fibers; work near base of pole, below ground. *b*, Mines of the pole borer near surface of ground. Natural size. (Author's illustration.)

usually sound. Even if the damage is not serious enough to cause the poles to break off under strain, they are likely to go down during any storm, and thus put the wire service out of commission; such damaged poles are a serious menace along the right of way of railroads. Poles that appear sound on the exterior may have the entire basal interior riddled, and the damage is not noticed until the poles break off. If merely isolated poles are injured so as to cause them to break off, they simply lean over, but if several adjacent poles are affected, especially where there is any unusual strain, that portion of the line is very likely to go down.

### THE PRINCIPAL INJURIOUS SPECIES.

The principal injurious species is the chestnut telephone-pole borer, or pole borer,[1] which is an elongate, creamy-white, wrinkled,

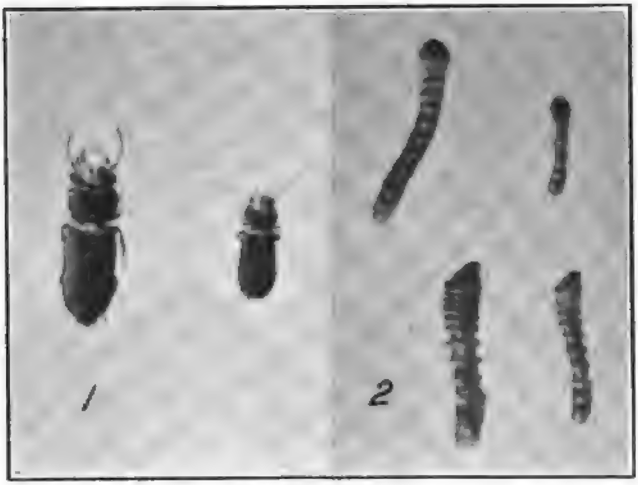


FIG. 2.—*1*, The pole borer: Male and female beetles. *2*, The pole borer: Young larvæ. *1*, Slightly enlarged; *2*, twice natural size. (Author's illustration.)

round-headed grub or larva (fig. 2, *2*). It hatches from an egg deposited by an elongate, mahogany-brown, shiny, flattened, winged beetle, from two-fifths to four-fifths of an inch in length (fig. 2, *1*). It appears that the eggs are deposited from August to October in the outer layers of the wood of the pole near the surface of the ground. The young borers, upon hatching, excavate shallow galleries in the sapwood, then enter the heartwood, the mines being gradually enlarged as they develop. As they proceed they closely pack the fine boring dust behind them. This peculiar semidigested boring dust, which is characteristic of their work, is reddish to dun-

[1] *Parandra brunnea* Fab. Since the publication of Bulletin 94, Part I, of this Bureau, this borer, first found to be injurious to chestnut telephone poles, has been found injurious to arborvitæ poles, and as it also injures telegraph poles, the name "pole borer" is more appropriate and comprehensive.

nish yellow in color and has a claylike consistency. The burrows eventually end in a broad chamber, the entrance to which is plugged with excelsiorlike fibers of wood. Here is formed the resting stage, or pupa, which transforms to the adult beetle. Often all stages, from very young grubs only about one-fourth inch long to full-grown grubs over 1 inch long, pupæ, and adults in all stages to maturity are present in the same pole. Adults have been found flying from July to September.

The insect attacks poles that are perfectly sound, but will work where the wood is decayed; it will not, however, work in wood that is "sobby" (wet rot), or in very "doty" (punky) wood. It has not yet been determined just how soon the borers enter the poles after they have been set in the ground. However, poles that had been

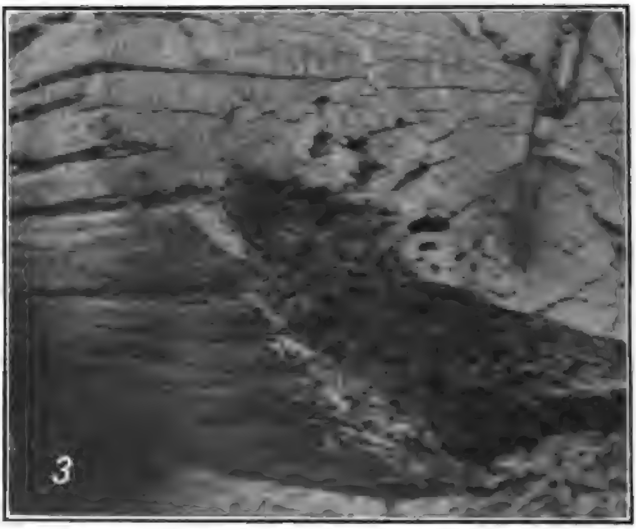


FIG. 3.—Damage to an untreated chestnut telegraph pole near surface of ground by the pole borer. (Author's illustration.)

standing only four or five years contained larvæ and adults of this borer in the heartwood, and poles that had been set in the ground for only two years contained young larvæ in the outer layers of the wood.

The presence of the borers in injurious numbers can be determined only by removing the earth from about the base of the pole; the large holes made when the adults come out are found near the line of contact with the soil. Often large, coarse borings of wood fiber project from these exit holes. Sometimes the old dead parent adults are found on the exterior of the poles underground. During August the young adults may be found in shallow depressions on the exterior of poles below the ground surface.

### INJURY BY OTHER INSECTS.

It is not to be concluded that injury by the pole borer is the only type of insect damage to poles. Indeed, a very common injury is by white ants, or termites. In lines from 10 to 12 years old serious damage by these insects occurred in as high as 15 per cent of the poles, and their work is often present, at least superficially, in as high as 75 per cent of the poles under all conditions of site. The damage, however, is usually to the outer layers of the wood, where it is moist or there is incipient decay, and is more superficial and localized than that of the pole borer. Nevertheless, the sound heartwood of poles is often completely honeycombed, especially at the base. The work of white ants is found both in sound wood, "doty" wood, and "sobby" wood. Sometimes a large channel runs up through the core of the heart and the sides are plastered with clay, forming a hollow tube with several longitudinal interior galleries. Their work often extends from 2 to 4 feet above the surface of the ground. They leave the outer shell of the wood intact and work up through the longitudinal weathering checks, covering the exterior of the pole with earth to exclude the light. White ants will damage poles that have been set in the ground only two years. Evidently they enter the pole from below the surface of the ground.

Injury by a giant round-headed borer is sometimes found in chestnut poles. The large mines of this borer are found in the sound and decayed wood of poles. Often where there is rot present the heartwood near the surface of the ground is completely honeycombed by this borer.

Longitudinal weathering checks in chestnut poles are often widened, and other defects enlarged by large, black carpenter ants and other smaller black ants, which thus hasten decay.

### KNOWN EXTENT OF THE DAMAGE.

The pole borer has seriously damaged as high as 10 to 15 per cent of the chestnut poles which have been set in the ground for from 10 to 12 years in lines in North Carolina, Virginia, West Virginia, Maryland, and the District of Columbia. It has only recently been determined that it has also seriously damaged a considerable proportion of the arborvitæ[1] telephone poles in part of a line in Illinois. It is evident, then, that this insect is an important factor in decreasing the normal length of service of chestnut and arborvitæ poles.

### POSSIBILITIES OF PREVENTING DAMAGE TO POLES.

Methods of treating poles superficially by brushing with various preservatives have proved to be temporarily efficient in keeping out wood-boring insects, if the work is thoroughly done and not

[1] *Thuja occidentalis.*

only the butt, but also the basal area, is treated. If the pole is not thoroughly brushed, the pole borer and other insects enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the base is left untreated, insects, especially white ants or termites, enter the pole from below ground and, avoiding the treated portions, come right up through the pole.

Impregnating the poles with creosote by some standard process (either by the open-tank or by a cylinder-pressure process) will keep out wood-boring insects. In the open-tank method only the area most subject to the attacks of wood-boring insects (i. e., the basal 8 feet) is treated, while by the cylinder-pressure processes the entire pole is impregnated.

Therefore, to effectually protect poles from the depredations of wood-boring insects it is recommended that they be impregnated with creosote by either the "open-tank" process or by a cylinder-pressure process.

Approved:

James Wilson,
*Secretary of Agriculture.*

Washington, D. C., *January 24, 1911.*

Issued April 22, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—CIRCULAR No. 133.
L. O. HOWARD, Entomologist and Chief of Bureau.

# THE ALFALFA CATERPILLAR.

BY

V. L. WILDERMUTH,

*Agent and Expert.*

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1911

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CEREAL AND FORAGE INSECT INVESTIGATIONS.

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CIRCULAR No. 133. Issued April 22, 1911.

# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE ALFALFA CATERPILLAR.

(*Eurymus eurytheme* Boisd.)

By V. L. WILDERMUTH, *Agent and Expert.*

### INTRODUCTION.

The insect under consideration in this circular is the caterpillar (fig. 1) of one of our most beautiful and common butterflies (figs. 2, 3) belonging to the group known as "the yellows," and is closely related to the well-known cabbage butterfly. The name "yellows" at once gives one an idea of the appearance of the adult, but this may be misleading, as the species is polymorphic, the coloration varying from a bright yellow (very frequently noticed), through an orange-sulphur (the most commonly noticed), to a pale white (the least often noticed).

FIG. 1.—The alfalfa caterpillar (*Eurymus eurytheme*): Larva or caterpillar stage. About twice natural size. (Original.)

For some years past the green caterpillars of this butterfly have been reported from various localities in the southwestern United States as feeding on, and in some cases doing a large amount of damage to growing alfalfa (*Medicago sativa*). It should be mentioned here that it is the caterpillar or worm stage of this species that does the damage, and not the adult butterfly. The latter feeds on the nectar of the bloom and in no way injures the plant. In fact, the writer has noticed these butterflies to all appearances springing the pollen triggers on the alfalfa blossoms while feeding, thus, should his observations prove correct, benefiting the plant for seed production.[a] In the year 1906 a correspondent of the Department of Agri-

[a] Though the author is quite confident of the accuracy of his observations, it is a case where misconception is exceedingly liable to occur; if correct, however, the fact is entirely new. See Dr. I. Urban, Verhandlung des Botanischen Vereins der Provinz Brandenberg, 1872, p. 13; Herman Muller, The Fertilization of Flowers, par. 93 and 94, 1873: C. V. Piper, Report of American Breeders' Association, 1909, Report of Committee on Breeding Forage Crops.—F. M. WEBSTER.

culture reported the caterpillar infesting the lucern fields in Bighorn County, Wyo., and in the year 1907 another correspondent reported it as a "cutworm," damaging the alfalfa at Hanford, Cal. This caterpillar is also known to have injured alfalfa in Utah. In 1909 Mr. C. N. Ainslie, of the Bureau of Entomology, found the eggs and larvæ of this species on alfalfa at Springer, N. Mex., but doing no apparent damage. In the same year Mr. E. O. G. Kelly, also of the Bureau of Entomology, found the larvæ feeding on alfalfa at Wellington, Kans. In Arizona, in the Salt River Valley and in the Yuma Valley, farmers say that on an average about one year in every three or four the "worms" become sufficiently numerous to cause considerable damage. In the Sacramento Valley, and in the irrigated alfalfa regions of south-central California, according to Mr. W. E. Packard, of the California Agricultural Experiment Station, the butterflies are quite numerous during certain years and cause more or less damage.

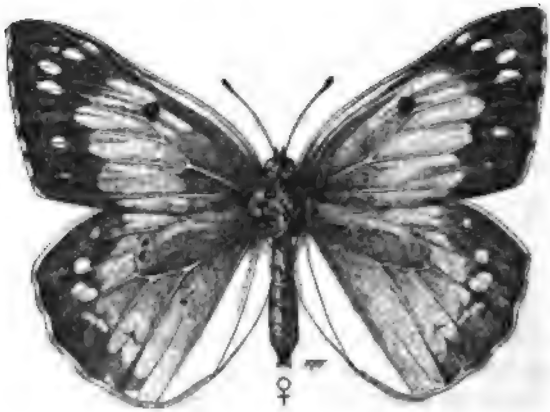

FIG. 2.—The alfalfa caterpillar (*Eurymus eurytheme*): Female in the adult or butterfly stage. One-half enlarged. (Original.)

However, not until alfalfa began to be widely grown in the newly irrigated region in the Imperial Valley of southern California did the butterfly assume such proportions, and appear with such regularity each season, as to become a dread to the farmers, particularly to those confining their efforts wholly to alfalfa growing. It was in 1909, after a season when the larvæ had taken all of one crop of hay, causing a loss of hundreds of dollars on his 320-acre ranch, as well as a similar loss to dozens of other ranchers in the valley, that Mr. J. A. Walton, of the Imperial Valley, wrote the United States Department of Agriculture asking for a remedy or a

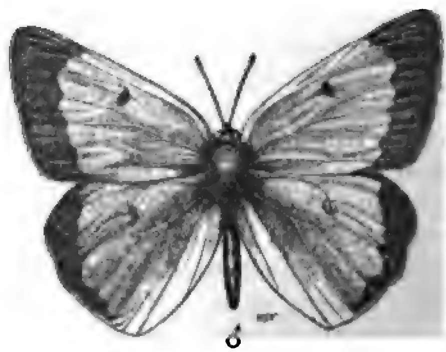

FIG. 3.—The alfalfa caterpillar (*Eurymus eurytheme*): Male in the adult or butterfly stage. One-half enlarged. (Original.)

method of dealing with the pest. As no remedy was known, plans were at once begun for investigating the outbreak and if possible working out some plans of controlling the same.

This circular is a partial report of the work done by the writer in the Imperial Valley the past season (1910), and while the investigation is still under way, another year being necessary to complete the same, it is thought desirable to give to the farmers in the alfalfa-growing section of the country the information secured, it being of such a nature as to be of great immediate benefit, if put to practical use, in controlling the pest.

### DISTRIBUTION.

According to Scudder, this species is more especially a western insect, being, as a rule, much more abundant west of the Mississippi River than east of it, and although its range extends eastward it is rather rarely found east of the Allegheny Mountains. In the West it occurs from Mexico northward into the Dominion of Canada, thus covering the chief alfalfa-growing section of the United States. It is especially abundant throughout the regions where irrigation is most extensively followed.

### DESCRIPTION OF THE SPECIES.

A meager description is given here of the various stages of development, in order to enable the casual observer to recognize the different forms:

*The adult* (figs. 2, 3).—The wings of the adults vary in color from yellow to white, being usually a sulphur-yellow above, with black outer margins, a conspicuous black spot in the center of each fore wing, and a faint yellowish spot in the center of each hind wing. The underside of the wings is of a lighter shade than the upper surface and is the side noticed when the butterfly is at rest with its wings folded above its back. The wing expanse is nearly 2 inches; in some it is a little less than this and in a few a little more.

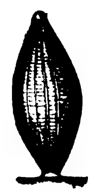

FIG. 4.—The alfalfa caterpillar: Egg. Greatly enlarged. (Redrawn from Scudder.)

*The egg.*—The eggs (fig. 4) are small, only 0.06 inch long, with from 18 to 20 slightly raised longitudinal ridges or ribs, broken by cross lines. They are elongated, white when laid, but turning reddish brown after the second day, and are deposited upright, with the basal end attached usually to the upper surface of the leaf. They are always deposited on fresh, green alfalfa, and never on dry or partially matured alfalfa.

*The larva.*—The full-grown larva (fig. 1) is usually 1 inch long, sometimes a little over, dark green in color, with a white stripe on

each side, partially broken by black and red dots at each spiracle. There is often an intermediate, narrower, and less distinct white line just above each of the lateral lines. In some specimens a black or dark-green median dorsal line is also present.

*The pupa.*—The pupa (fig. 5) is yellowish green, has no cocoon, and is found head end up, attached by two threads, one of them forming a swing, to an alfalfa stalk.

### INVESTIGATIONS IN THE IMPERIAL VALLEY OF SOUTHERN CALIFORNIA.

The investigations were begun by the author about the middle of March, 1910, and carried on through the summer until late in the fall of the same year. The writer was at first located on the J. A. Walton ranch, in the extreme southeastern part of the valley, and later at El Centro, where the work was carried on in cooperation with Mr. Walter E. Packard, an agent of the California Agricultural Experiment Station, to whom a great amount of credit is due for the assistance and timely suggestions offered.

FIG. 5.—The alfalfa caterpillar (*Eurymus eurytheme*): Pupa or chrysalis stage. Twice natural size. (Original.)

The Imperial Valley is a place unique in location and altitude. It is an irrigated region entirely surrounded by mountains and desert. The major part of the valley lies below sea level—some of it, in fact, as much as 250 feet below. The weather is warm most of the year and hot the rest of the year. It hardly ever rains, and the humidity is usually very low. The growing season extends over practically the entire year, there being an entire lack of freezing weather during some winters. On the average there is not during the year more than one month of weather that could be called winter weather.

The conditions just referred to serve to explain the immense numbers of these butterflies in the valley. The period over which the butterflies are able to continue breeding without being molested is very long, being from March to December. Then, too, owing to the very low humidity there is usually insufficient moisture to permit the development of what appeared to be a contagious disease, resembling in effect *flacherie* of the silkworm. This disease was found to be largely responsible for keeping this butterfly in check in other parts of the State of California and in southern Arizona.

### SEASONAL HISTORY IN THE IMPERIAL VALLEY.

On the 15th of March, 1910, several adult individuals, possibly adults that had issued from hibernating pupæ, were caught in the act of flying over alfalfa fields and placed in a large mosquito-bar

cage which covered an alfalfa plant. These immediately deposited eggs. It can be said, therefore, that the hibernating forms issue between March 1 and March 20. The season of 1909-10 was exceedingly cold in the valley, while that of 1910-11 was, up to the middle of February, precisely the reverse, and up to the 8th of this month larvæ had been found present in limited numbers in the fields. It seems, therefore, probable that during some winters the species may breed throughout the entire season, as sometimes there is hardly a frost. Either the larval or pupal stage, or both stages, would during such winters be merely lengthened, for that is really what happens in the spring or fall of the year, and thus the insect could hardly be said to hibernate. However, eggs were being laid on March 15, and possibly a few days earlier, and these gave rise to the first or spring generation. This generation was very slow in developing, requiring about 44 days, the egg stage being 6 days, the larval stage 30 days, and the pupal stage 8 days. As the weather became warmer each of these periods gradually lessened until in the third generation only 22 days were required for complete development, the egg stage in this case being 4 days, the larval stage 12 days, and the pupal stage 5 days. These were the periods of development for individuals confined in cages; in the field a few days longer, often as many as four or five, seemed to be required for development from egg to adult.

The first generation covered the period from March 15 to April 30; the second generation from May 1 to May 28; the third generation from May 28 to June 20; and the fourth generation from June 20 to July 15. There were thus four distinct generations, the last being less distinct than the others. Later in the year the generations became so largely confused that it was impossible to separate them. Just as the fourth generation was beginning to pupate, the supposedly contagious disease before mentioned killed a large majority of the larvæ present at the time, and thus observations along life-history lines were checked. From this time on, scattering individuals produced eggs and gradually increased in numbers up to October, after which time quite a few worms were present in some fields, and often considerable damage was noted. In fields that had been green during August, when the water supply was short in the valley, there were always more of these caterpillars noticed than there were in fields that had not been green during the month stated. This was due to the fact that the worms were able to feed in these green fields, and therefore in the fall there remained quite a number of adults. By the middle of October, as the nights became cool, the larvæ and pupæ did not develop as rapidly as during the summer months, and the species just held its own in numbers up to December 28, 1910, when all were in the hibernating stage.

TWO CLASSES OF RANCHES—PASTURE RANCHES AND HAY RANCHES.

The alfalfa ranches in the Imperial Valley, Cal., can all be divided into two classes: (1) Pasture ranches, or those devoted entirely to the fattening or pasturing of cattle and hogs, and (2) hay ranches, or those on which the crop is utilized for hay. For convenience we can look at these separately.

*Pasture ranches.*—It was noticed early in the summer, and the writer's attention was called to the fact by a number of farmers, that ranches devoted to the raising of stock, either cattle or hogs, were rarely, if ever, seriously affected by the pest. On some dozen such ranches visited and inspected very few worms could be found, and the butterflies flying over the fields were never numerous. At first this was considered entirely due to the fact that there was hardly ever any bloom present for the adults to feed upon and that the greater part of the fields was kept grazed quite closely, making the condition in pastured fields less favorable for the laying and development of the eggs. Under such conditions the number of eggs deposited is greatly reduced. Many of the eggs laid on the young growth under such conditions are destroyed by the grazing of the stock, and the percentage that develops is kept to a minimum. Later in the season it was noted that on the stock ranches visited the disease previously mentioned, which is common to lepidopterous larvæ, was more prevalent than on hay ranches. All the factors determining this difference have not been ascertained, but the fact itself is quite significant.

On some of the ranches coming under the writer's observation the alfalfa was allowed to grow for some four weeks, or until it reached the height of about 20 to 24 inches. Cattle were then turned into the field, and within a few days the alfalfa became trampled. The ground and the alfalfa were very moist, there being more or less dew present every morning, and droppings from the cattle and hogs naturally brought about a foul condition in the field, assisting in the retention of moisture. Whether as a result of these conditions or as a coincidence, the contagious disease appeared to the writer to be much more prevalent in these fields than elsewhere.

*Hay ranches.*—It is on ranches and fields from which successive crops of hay are taken that the height of the damage is reached. In such fields the conditions for the development of the species are as nearly ideal as possible, and here the worms are ordinarily unmolested in their feeding and growth. The period elapsing from the time that one crop is cut until another is ready to harvest so nearly coincides with the length of the period necessary for the development of any one generation of the butterfly that the cutting of the hay, as ordinarily carried on, does not reduce their numbers or disturb their work, since the worm will likely be in the advanced stage

or, perhaps, have passed into the pupal stage before the crop is cut off.

Many fields observed by the writer were attacked in strips or patches. Sometimes one border would be almost totally devoured, while an adjoining plot would not be molested. Again, in other fields irregular patches would be attacked and the rest of the field not materially injured. In cases where whole borders of alfalfa were injured, the time and amount of water applied in irrigating produced an uneven growth, and as the generation of butterflies, on issuing, chose for egg-laying the strip that was the greenest and freshest, this strip would be the one damaged. It seems possible to account for the irregular patches in the same way—that is, considering that these patches were ones that were held back because of the condition of the soil. The soil conditions in one part of the field may be quite different from those in another part of the same field, and thus a varying growth of the crop results, which would be attacked in patches.

### FOOD PLANTS.

Besides alfalfa the larva is known to feed upon the two buffalo clovers, *Trifolium reflexum* and *T. stoloniferum*, which probably constitute its original native food plants. It also feeds upon white clover (*T. repens*), and in California on *T. tridentatum*, but is said not to attack red clover (*T. pratense*). Other food plants noted by Scudder are Hosackia, ground plum (*Astragalus caryocarpus*), and *A. crotalariæ*. The butterfly is known to oviposit on *Medicago hispida*, and at Indio, Cal., on July 1 the writer found larvæ feeding on sweet clover (*Melilotus alba*), which strangely enough they seemed to prefer to a patch of alfalfa growing close by. Eggs were also observed to be very numerous upon the leaves of the sweet clover at the same time.

### INSECT ENEMIES.

The white eggs of tachinid flies were always in evidence wherever any larvæ were to be found, and the young of these destroy quite a large number of worms. In one instance it was noted that as many as 15 per cent of the worms had tachinid eggs on them. Because of the supposedly contagious disease, as shown in a following paragraph, little success resulted from rearing these parasitic flies. Five specimens were reared from the larvæ of Eurymus. These were all of the species *Euphorocera claripennis* Macq. (fig. 6). One specimen, determined by Mr. D. W. Coquillett, of this bureau, as *Masicera* sp., was reared from the pupa of Eurymus.

Two species of hymenopterous parasites were reared. From the Eurymus larvæ several specimens of *Limnerium* sp.—all females, how-

ever—were reared, while one specimen of *Chalcis ovata* Say (fig. 7) was reared from a pupa of Eurymus. It seems from this that the hymenopterous parasites are much in evidence, although if the material had not been affected by the supposedly contagious disease many more might have been secured.

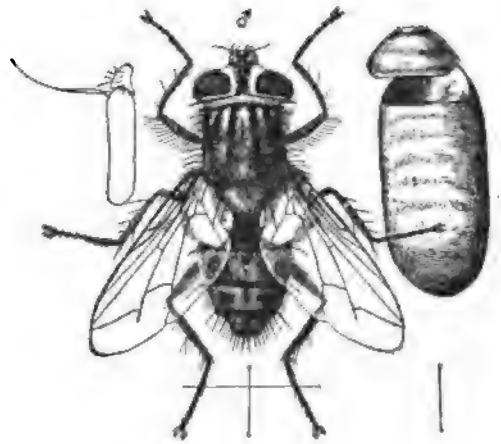

FIG. 6.—*Euphorocera claripennis*, a parasite of the alfalfa caterpillar: Adult and enlarged antenna of same; puparium. Enlarged. (From Howard.)

*The cotton bollworm mistaken for an alfalfa caterpillar.*—A large green caterpillar known as the bollworm, *Heliothis obsoleta* Fab. (fig. 8), that can be distinguished from the Eurymus because it is of a lighter green color, about one-fourth larger, and hairy and rough in appearance rather than smooth, with three black lines traversing its body lengthwise, is quite prevalent in the Imperial Valley, and is often mistaken for the alfalfa caterpillar by many farmers. Mr. E. O. G. Kelly and Mr. T. H. Parks, agents of the Bureau of Entomology, working at Wellington, Kans., in the summer of 1909 also noted this species and reported it as being of a predaceous habit.[a] As noted in the valley, it was found to do very little damage to alfalfa, but to be a ravenous enemy of the alfalfa

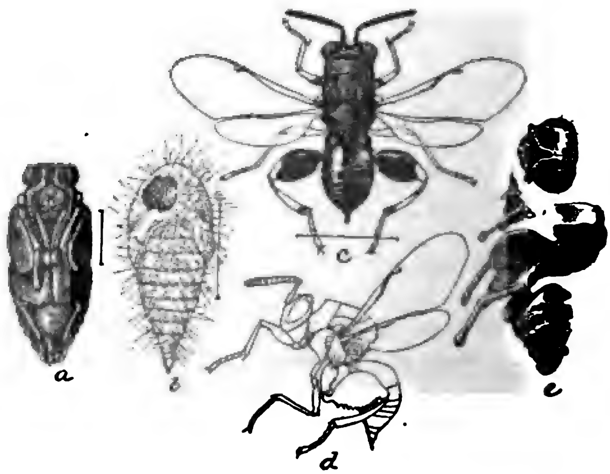


FIG. 7.—*Chalcis ovata*, a parasite of the alfalfa caterpillar: *a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

[a] This cannibalistic habit has also been observed in Texas by Quaintance and Brues. Bul. 50, Bur. Ent., U. S. Dept. Agr., pp. 79–80, 1905.

caterpillar, never eating alfalfa as long as it could find the larvæ or pupæ of Eurymus around.

One of these larvæ ate 5 larvæ of the Eurymus during a single day, and on May 25 the writer counted many dozens of pupal cases in the field that had the contents eaten out. Each case had an irregular opening eaten into it; sometimes the end of the abdomen would be eaten away, and again the opening would be on the side, often the entire side being destroyed. Upon further search the larvæ of Heliothis were found in the act of devouring the pupæ and were thus responsible for the damage.

### OTHER NATURAL ENEMIES.

*Larval disease.*—The most common natural enemy observed was a supposedly contagious disease which there has not yet been an opportunity to carefully study. This was prevalent all over the valley and is present at all seasons. It destroys both the pupa and larva, but more often the larva. The worms when attacked by the disease turn a lighter green, become sluggish, and in a day or two are nothing but a soft, decayed mass, usually found hanging to the alfalfa stalks. The development of the disease apparently depends upon moisture, as it is more often noticed in moist fields. The fact that it does not at all times keep the worms in suppression is without a doubt due to the fact that the climate of the Imperial Valley is very dry. Larvæ brought to the laboratory for rearing of insect parasites and for life-history studies in a large percentage of cases died of the disease as soon as confined. A quantity of worms sent to Berkeley, Cal., by Mr. Wilsie, of the Imperial Valley horticultural commission, for experimental rearing of parasites, all died of the disease, either before reaching their destination or the day after. During the first week of July the humidity was exceptionally high for the Imperial Valley, and at the time about 95 per cent of the larvæ in the valley succumbed to disease, thus saving a hay crop for a great many of the farmers, but stopping experiments almost completely. It is probable that this disease has occurred in years past, and it may occur in future years, at some time during the summer season, in such abundance as to destroy a brood, as it did in the past year (1910).

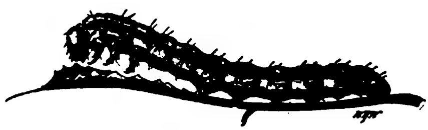

FIG. 8.—Bollworm (*Heliothis obsoleta*), an enemy of the alfalfa caterpillar. Twice natural size. (Original.)

It seems to be partly due to this disease that the alfalfa caterpillar does not appear in such large numbers in other regions of the Southwest, notably in alfalfa regions in Arizona. Here there seems to be greater humidity and more moisture, and the disease is able to keep the number of worms reduced to a minimum.

It is the intention of the Bureau of Entomology to repeat these observations and experiments in the Southwest during the summer of 1911, and in order to do so the bureau would be glad to cooperate with any farmers who wish to put their farms or ranches under a rigid system of control. The greater the number of farmers following this plan the greater the beneficial results that may be expected.

## METHODS OF CONTROL.

### INSECTICIDES.

In dealing with insect pests affecting cereal and forage crops it has proved possible in only a few instances to control them by the use of any of the various insecticides or poisons. The reason for this lack of success lies largely in the fact that such crops are distributed over a wide area and the expense of application of any insecticide as a control measure is necessarily high, while a lack of thoroughness is likely to arise when one tries to keep the expense of treatment down to an economical basis.

Since the alfalfa hay is fed to stock, it is not possible to use any of the arsenical poisons against the caterpillar of the alfalfa butterfly. A few experiments were tried by using pyrethrum or "buhach." As this is not a poison, and since its fatal effect upon the larvæ of butterflies is produced externally through their breathing pores, there would thus be no danger to stock. Pyrethrum was used in one case at full strength, and in another instance it was diluted with equal proportions of flour. An application was made by dusting this substance from a cheesecloth sack, following the primitive method of applying Paris green to potato vines, at the rate of 3 pounds of pyrethrum to the half acre, which in the case of diluted material would make 1½ pounds of pyrethrum to the half acre. This first test was tried on July 8, and no results were obtained, because of the fact that just two days later practically all of the worms in the field where the test was being made were destroyed by the malady before mentioned. The same experiment was repeated, however, on September 22, and in this case also the results were negative, not a caterpillar being killed. It would seem, therefore, that the application was not sufficiently heavy to kill the worms, and that to have increased the amount of pyrethrum applied might have resulted in the eradication of the pest; but as the cost of pyrethrum at the rate of 3 pounds to the acre is already nearly $2, without considering the expense of application by hand, this would be out of consideration from an economic point of view. However, the excellent results obtained through the use of pyrethrum in the case of other insects will justify further experimentation along this line, and it may be possible to use it in the smaller fields.

SYSTEM OF CROP CULTURE.

For the reasons just given the control problem, in dealing with this alfalfa pest, resolves itself to one of the method of handling the crop. Not long after the Bureau of Entomology began observations in the Imperial Valley the writer was informed by well-to-do ranchers that not all alfalfa fields or even all ranches were affected by the caterpillars, there being apparently certain conditions regulating the devastation. One cause for this, as noted earlier in this paper, was the presence of stock in certain fields, but even in hay ranches there was a variation in the numbers of the caterpillars. Accordingly there was outlined a series of experiments in which, in certain fields under observation, definite methods of management were tested to see whether some of them would not reduce or perhaps entirely eliminate the damage. Before describing the conditions existing in these fields it would be well to consider, first, the conditions existing in certain other alfalfa fields not under the direction of the agents of the bureau which suffered greatly because of the pest, the owners often losing an entire crop. The first fact noted was that the caterpillar damage in such fields seemed to be correlated with the condition of the soil. A field seriously damaged often revealed a poor soil; at least, a soil not well adapted to alfalfa culture, and consequently producing a slow-growing crop. Of course, not all the fields damaged were of such poor soil, for some of the very best alfalfa fields were seriously ravaged, but in these latter cases this was attributable to other factors, such as time and careless manner of cutting and time of irrigation. The sandy loams or light soils are the best for alfalfa production, and consequently least damaged. A heavy soil can be greatly improved and the growth of the alfalfa increased by deep plowing and thoroughly preparing the seed bed at time of seeding the crop and then renovating the alfalfa yearly by disking or by the use of an alfalfa renovator.

The worst conditions noted were those in which the attack of the caterpillar was due to delayed cutting of the hay crop and due quite often to the fact that many of the ranchers were trying to cultivate more land than it is possible for one man to farm successfully. With such ranchers some of the following defects are observable in their treatment of the hay crop: First, there is often insufficient water used to provide for the prompt development of the alfalfa crop. An abundance of water is very necessary, as it enables the alfalfa to make faster growth, and thus the farmer can reap his crop sooner and before the caterpillars have effected much damage. Second, the crop is not cut early enough in the majority of cases—about 90 per cent—that is, the alfalfa is too far advanced in bloom when cut, and this delayed cutting enables the caterpillars to mature successfully. The

alfalfa should be cut just when it is beginning to bloom. Other noticeable factors which tended to hamper control measures were that at haying time the crop was cut high, the turning corners were left ragged, and the ditch banks and borders poorly mowed, if at all, and thus the caterpillars that were present and had not gone through to the adult stage had a large amount of material upon which to develop, and soon did so, so that the butterflies from these were ready for the next crop. These places would also afford bloom which would naturally attract the butterflies.

For fields in which good cultural conditions were to be created and in which methods were to be inaugurated that would not further the development of the caterpillars, 10 locations were selected and used as a basis of work. From what was said in the previous paragraph it will be readily seen that the thing to be done in these fields was to put them under a system that would remedy all or part of the defects noted in other fields.

As has been mentioned before in this paper, four generations of caterpillars were observed in the Imperial Valley the past year (1910). A large part of the damage was due to the caterpillars of the third and fourth generations, the first and second not being numerous enough to assume any serious aspect. The task, then, was to keep their numbers below the point at which they could do any considerable damage. The time to start this control work was naturally with the earlier generations. The ten fields mentioned (no two of which had had the same conditions of culture previous to that year, and which had all suffered more or less damage the year before, namely, in 1909) were given what might be termed clean culture, or careful management. Just as soon as possible after removing a crop of hay, using the methods to be described later, the field was irrigated thoroughly, thus starting the growth quickly. The field was again irrigated as soon as the dry condition of the crop required, and thus the growth was forced and not allowed to be checked. It takes about 28 days to produce a hay crop in the Imperial Valley, a little longer than this in the spring and fall, and a few days less in warmer weather. It also takes just as many days as has been shown under "seasonal history" for the butterflies to develop from egg to adult. Now if the crop of hay be forced by frequent watering, or because of good soil conditions, the worms will not have gone into the resting stage at time of cutting, but, instead, will still be feeding on the green alfalfa, and when the hay is cut and removed conditions are rendered unfavorable for their development and their food supply will be correspondingly reduced. Therefore, the hay should be cut just as it is coming into bloom, which is a few days sooner than it is generally thought advisable to cut it, as a generation of worms will take a whole field in a short time. Thus not only will the hay

be saved, but the major portion of the larvæ, finding a lack of the food necessary for their complete development, will ultimately perish. To bring about this condition, however, it is necessary to mow the field carefully, leaving no high stubble. The turnrows, borders, and ditch banks should also be closely mown, as this will not only reduce the supply of food for the larvæ but also that of the butterflies, as such plants will afford considerable bloom. In two cases in the writer's experiments it became necessary to remow the fields at a cost of from 30 to 50 cents per acre, and then in all cases to irrigate promptly. As a result of this procedure a large percentage of the caterpillars failed to develop to the imago or butterfly stage. Deducting these, together with the larger number that failed to reach the pupal stage, it will be seen that there were many hundred less worms to attack the next crop, as each butterfly developing from them would have deposited at least 100 eggs. In some fields, instead of irrigating immediately after the hay was removed, the experiment was tried of letting the field go dry for several days, and thus starving the worms. While this gave good results it was not as satisfactory as the method of immediate irrigation, for there was always enough moisture in the field to start the new crop going and thus provide a little food for the caterpillars.

The complete success of these methods is dependent on cooperation among the farmers, for the larger the percentage of those who inaugurate a good cultural system the greater will be the benefit derived therefrom. The butterflies, however, do not fly very long distances, and as long as the conditions are favorable for their existence on one field or on one ranch they will remain there. They may, however, fly considerable distances when forced to do so for want of food or for fresh green alfalfa on which to deposit eggs or when driven by the wind, and thus it is that one farmer can secure, by his individual efforts, such remarkable results as are reported below.

### RESULTS OBTAINED.

Of the ten fields cultivated according to these methods only one was damaged by the caterpillars up to July 10, the date on which so large a number of them were killed by the disease previously mentioned. This one field was damaged because irrigation had been delayed for nearly two weeks after the cutting of the second crop, owing to a new ditch which was under construction. Being a thrifty field naturally, the alfalfa had made a start, assisted by the moisture still present in the ground, and butterflies coming in from an outside field deposited eggs on this new growth, thus enabling the worms to destroy the best of the crop after it was finally irrigated. As a result almost an entire crop was lost. A field adjoining on the south, which had been

irrigated immediately after cutting, was not in the least damaged. This was a lesson in itself, as it indicated the necessity for prompt work.

### PROTECTIVE MEASURES ADVISED.

Thus from a comparison of observations made in the two classes of fields it is possible to derive the following rules for handling the crop:

Do not abandon a field because the caterpillars are beginning to damage a hay crop. If the caterpillars threaten the destruction of a crop of alfalfa before the hay can possibly mature, mow it at once, cutting it low and clean, and in so doing starve a large majority of this generation of worms, thereby protecting the next crop as well as saving a part of the one already affected.

Get the ranch in the best possible cultural condition. Irrigate often and thoroughly and as soon after cutting as the crop of hay can be gotten off the ground.

Cut close to the ground and clean, especially along the ditch banks, borders, and turnrows, as well as in the main part of the field.

Cut the crop early. When just coming in bloom is the proper time. Watch for caterpillars in the early spring crop, and if many are observed about grown cut the hay a few days before it is in bloom, and thus save the next crop.

Pasture alfalfa whenever possible, as a minimum amount of damage occurs in such fields.

Use the methods just mentioned on early spring crops, no matter whether any worms are noticeable or not, and thus avoid any risk of having overlooked them. The satisfactory results must come from an application to an early crop.

Renovate every winter, either by disking or by the use of an alfalfa renovator, thus disturbing any pupæ that may be wintering over, and putting the land and alfalfa in condition for good growth the following spring.

These methods, while they will probably be of value in other sections, have been tried only in the Imperial Valley of California, and they are not specifically recommended for sections where climatic and other conditions differ from those found in this valley.

Approved.

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *January 26, 1911.*

[Cir. 133]

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 135.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE ASPARAGUS MINER.

BY

F. H. CHITTENDEN, Sc. D.,

*In Charge of Truck Crop and Stored Product Insect Investigations.*

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CIRCULAR No. 135. Issued March 25, 1911.

# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

## THE ASPARAGUS MINER.[a]

(*Agromyza simplex* Loew.)

By F. H. CHITTENDEN, Sc. D.,
*In Charge of Truck Crop and Stored Product Insect Investigations.*

The stalks of asparagus are frequently attacked by insects, and in recent years have been reported considerably injured by the larva or maggot of a minute black fly to which the name asparagus miner has been given. The larva mines beneath the epidermis of the stalk, and when it has transformed to the puparium or "flaxseed" stage the thin outer skin becomes more or less ruptured and the presence of the insect is easily detected. It operates more abundantly near the base

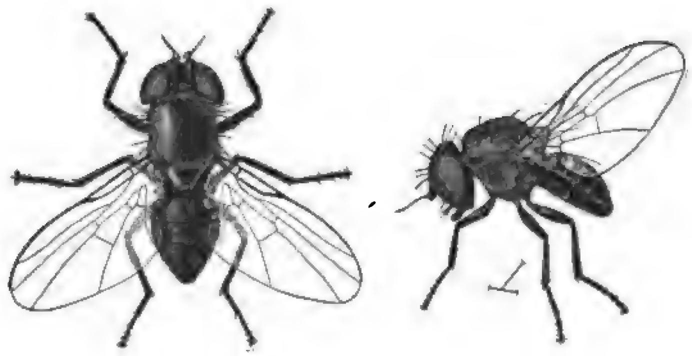

FIG. 1.—The asparagus miner (*Agromyza simplex*): Fly, dorsal view at left, lateral view at right. Highly magnified. (Author's illustration.)

of the stalks and penetrates below the surface of the ground to a depth of 7 or 8 inches. During the year 1906 this species attracted considerable attention by its abundance in some of the principal asparagus-growing sections of New England and it bids fair to become a pest of considerable importance. It was first noticed on asparagus in 1896, prior to which time nothing was known of its habits. It is a native species and evidently restricted to asparagus as a food plant. Until the year 1906 it had not been recognized as doing injury to cutting beds, although attack had been observed in various sections.

[a] Revised reprint from Bul. 66, n. s., Bur. Ent., U. S. Dept. Agr.

The mines of the larvæ about and below the bases of the stalks are frequently so abundant that they have the effect of girdling, so that the injured stalks can readily be pulled from the ground.

### DESCRIPTIVE.

The parent insect is a two-winged fly (fig. 1), metallic black, with large prominent head and eyes, and clear wings, the wing expanse being about one-sixth of an inch (4 mm.).

The larva (fig. 2, *a*) is about one-fifth of an inch long and milk-white in color. Like other maggots, it is footless, large at the posterior extremity, and tapering toward the head.

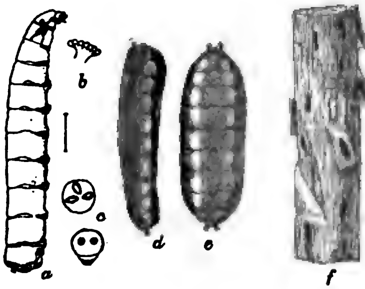


FIG. 2.—The asparagus miner (*Agromyza simplex*): *a*, Larva, lateral view; *b*, thoracic spiracles; *c*, anal spiracles; *d*, puparium from side; *e*, same from above; *f*, section of asparagus stalk, showing injury and location of puparia on detached section. *a–e*, Much enlarged: *f*, slightly reduced. (Author's illustration.)

The puparium (fig. 2, *d*, *e*) is not unlike the "flaxseed" of the pernicious Hessian fly, with which it has been aptly compared. At a little distance, also, it suggests a Lecanium scale. This stage is remarkable because of its peculiar flattened and curved position, as seen from the side. It is red in color, and measures about 3.5 mm. in length and about 1 mm. in width.

The egg has not been observed.

This species belongs to the dipterous family Agromyzidæ, and was described by Loew in 1861,[a] the locality being given as "Middle States."

### DISTRIBUTION.

In its injurious occurrences this species appears to be limited to the eastern United States, from New England to Tennessee. From available data it is quite obvious, however, that it may be destructive over a considerable territory, including a large portion of Massachusetts and Connecticut, Long Island, the District of Columbia, Pennsylvania, and Tennessee. As it is recorded from New Jersey, it is probably injurious there, although no reports of injury in that State have reached this office. In time it will doubtless attract attention in intermediate points and in States farther north and west. It has also appeared in asparagus beds in California.

### HISTORICAL AND BIOLOGICAL NOTES.

In May, 1897, and afterwards this fly was observed in abundance by the writer on terminal shoots of asparagus, particularly at Cabin John, Md. Two weeks later no more flies were seen, but June 26

[a] Diptera Americæ septentrionalis indigena, Centuria octava 84, p. 160.

they reappeared and were then usually seen *in copula*. It was surmised at the time that this second appearance indicated the first new generation of the year and its abundance on asparagus seemed to show that it lived in some manner at the expense of that plant. Examination of asparagus plants at that time, however, failed to show attack.[a]

In 1900 complaints of injuries were made in the District of Columbia, and at Knoxville, Tenn., and in the meantime the species came under the observation of Mr. F. A. Sirrine, who stated[b] that work was first observed in asparagus fields on Long Island in 1896. Late in September, 1900, word was received of injury to asparagus from Tennallytown, D. C. When the writer visited the field, although injury was apparent on the outer skin of some stalks, no living specimens could be obtained, only the dried puparia being in evidence at that time. October 2 of the same year, Mr. Samuel M. Bain, University of Tennessee, Knoxville, Tenn., sent a stalk of asparagus showing the work of this miner upon the skin, and, October 27, specimens of the dried puparia.

February 18, 1901, it was reported at Philadelphia, Pa., that this insect seemed to cause much greater trouble than the common asparagus beetle. Two or three new beds of asparagus were lost on account of its ravages.

By the writer's direction, Mr. F. C. Pratt visited a truck farm at Brookland, D. C., where asparagus was one of the main crops, June 18, 1902. Asparagus was still being cut for market, but volunteer plants were growing here and there in fields of corn, cantaloupe, and potatoes, between rows. A few flies were seen on terminal shoots of asparagus that showed wilting, and many volunteer plants were badly infested, most individuals having transformed to pupæ. Although stems break off just below the ground, the entire colony of insects below that point is left with sufficient moisture and nourishment for their maintenance. The puparia were present in great numbers underneath the outer skin of the root, and as many as nine puparia were counted in a space only an inch long on one stalk. The stalks below the point of injury appeared to be perfectly sound. Larvæ also were found in rotting stalks that broke off just below ground.

During September, 1906, Messrs. J. B. Norton and A. D. Shamel, of the Bureau of Plant Industry, furnished stems of asparagus from Concord, Mass., showing severe infestation by this species, many puparia being present under the mined outer skin. In the neighborhood of Concord, a very important asparagus-growing region where hundreds of acres are devoted to this crop, infestation was practically absolute, the insect being as abundant as the common asparagus

[a] Bul. 10, n. s., Div. Ent., U. S. Dept. Agric., p. 62, 1898.

[b] Bul. 189, N. Y. Agric. Exp. Sta., p. 277, Geneva, 1900.

beetle, and present wherever rust was found, as also where no rust was present. Some plants showed injury 7 inches below the surface.

Later Mr. Shamel reported finding infestation in every field and patch of asparagus which he visited in Massachusetts and Connecticut, particularly at Suffield, Granby, and Hartford, Conn., and he believed attack to be widespread.[a]

October 26, 1906, Mr. Ralph E. Smith wrote that the conditions under which this asparagus miner was found in abundance in the yellow stalks of asparagus in California, as reported by him in an article on Asparagus Rust Control,[b] had prevailed for two or three years. The insect was always very abundant at the base of yellow, dying stalks, although injury was attributed to the "centipede," reported as wireworms on a previous occasion.[c]

The asparagus miner was reported by Mr. I. J. Condit in the vicinity of Antioch, Cal., August 19, 1908, where the common asparagus beetle was also abundant. The miner was equally numerous and stalks showing infestation were received. The miner-infested stalks could generally be detected by their roughened appearance near the ground. This species was also taken at Oakley, and it seems probable that it is becoming generally distributed in California. In one place at Oakley Mr. Condit observed the miner quite common on some stalks.

During October, 1908, the writer observed this species well established on asparagus in the vicinity of Portsmouth, Va. In October, also, very severe injury was reported to asparagus in the vicinity of Concord, Mass. The roots of the plants were not only girdled, but the miners worked up the stalks some inches above the ground.

## REMEDIAL MEASURES.

With our present knowledge of the life economy of this species, two methods of control suggest themselves as of greatest value, and it may be that they will prove all that is necessary under ordinary conditions.

(1) In spring permit a few volunteer asparagus plants to grow as a trap crop, to lure the fly from the main crop or the cutting beds for the deposition of her eggs. After this has been accomplished the trap crop should be destroyed by pulling the infested plants and burning them with their contained puparia. The time to pull the plants will vary according to locality and somewhat according to season also. The second and third week in June would be about the right time in and near the District of Columbia. On Long Island this work should be done a week or two later. In the northernmost

[a] Its occurrence at New Haven, Conn., is recorded by W. E. Britton (6th Rept. State Ent. Conn. for 1906, pp. 303–306, 1907).

[b] Bul. 172, Univ. Cal. Agric. Exp. Sta., p. 21.

[c] Bul. 165, loc. cit.

range of this insect—for example, in Massachusetts—the last week of June would be a suitable time.

These plants must be destroyed before the end of the cutting season, otherwise they are apt to provide abundant rust infection.

(2) The second generation can be destroyed in like manner by pulling old infested asparagus stalks as soon as attack becomes manifest and promptly burning them also.

If this work were carefully done over a considerable area, it would leave little necessity for other methods, since it would do away with these insects in the vicinity and leave few to be dealt with another season; unless, indeed, this insect has an alternate food plant. Thoroughness and the cooperation of neighboring asparagus growers are essential for success.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *January 31, 1911.*

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Issued March 31, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—CIRCULAR No. 136.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE DISTRIBUTION OF THE ROCKY MOUNTAIN SPOTTED-FEVER TICK.

BY

F. C. BISHOPP,

*Agent and Expert.*

81261°—11

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1911

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United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE DISTRIBUTION OF THE ROCKY MOUNTAIN SPOTTED-FEVER TICK.

(*Dermacentor venustus* Banks.)

By F. C. BISHOPP,
*Agent and Expert.*

The demonstration of the fact that Rocky Mountain spotted fever, an important disease of man, is conveyed by the common wood tick of the Rocky Mountains, has naturally attracted considerable attention. In the year 1902 Drs. Wilson and Chowning advanced the theory that the "wood tick" acts as a carrier of the disease. In 1906 the late Dr. H. T. Ricketts began a series of admirably planned and executed experiments which showed that the tick *Dermacentor venustus* Banks is principally, if not entirely, responsible for the transmission of this disease to man.

While the disease appears in its most virulent form in the Bitter Root Valley in western Montana, it is known definitely to occur in a less severe form in parts of Idaho, Wyoming, Utah, and Nevada. Although no authentic records to that effect are to be found, there is little doubt that it occurs occasionally in certain sections of Colorado and Oregon. In the Bitter Root Valley from 70 to 80 per cent of the cases terminate fatally, while in southern Idaho there is a mortality of about 5 per cent. The cases of the disease which have appeared in the other States mentioned seem to be of this less virulent type.

Since it has been determined that a tick is the transmitter of this disease, the importance of ascertaining the distribution of the species concerned is at once apparent. In 1909 Prof. R. A. Cooley, as Entomologist of the Montana Agricultural Experiment Station, undertook the determination of the distribution of this tick in the State of Montana. He accumulated 172 lots of ticks, including 142 lots of *Dermacentor venustus*, from 49 localities. During the same season

Mr. W. V. King was employed as an agent of this bureau for the purpose of collecting specimens especially outside of Montana. In this investigation he worked under the general direction of Mr. W. D. Hunter, but under the immediate supervision of Prof. R. A. Cooley. At the same time Mr. J. D. Mitchell, Mr. F. C. Pratt, and the writer, as agents of the Bureau of Entomology, made collections in the southern and central portions of the Rocky Mountain region. In 1910 Mr. W. D. Hunter formulated plans for obtaining further information regarding the distribution of the species. By the use of circular and personal letters, the aid of several hundred individuals throughout the Western States was obtained. Through the cooperation of these correspondents a large number of ticks was procured. All of the material was sent to the laboratory at Dallas, Tex., where the immature ticks were reared to adults and all specimens were carefully determined. Mr. Nathan Banks, a specialist in this group of animals, identified much of the material received during 1909.

## WHERE THE TICK OCCURS.

As a result of this investigation the distribution of the spotted-fever tick, as shown by the accompanying map (fig. 1), was determined. The map includes a number of localities in Montana where, in 1909, Prof. R. A. Cooley determined the species to occur. Our knowledge of the distribution is based upon 1,300 lots of ticks, 815 of which were *Dermacentor venustus*. The specimens of this species were obtained from 225 different localities. The numbers of localities in the different States in which this tick was collected are as follows: California 3, Colorado 15, Idaho 42, Montana 72, Nevada 11, New Mexico 2, Oregon 15, Utah 12, Washington 27, Wyoming 26. The shaded portion of the map includes all of the localities where the tick has been found. The darker shading indicates the regions where the species occurs in greatest abundance. There is no doubt that there are areas of considerable extent, within the territory indicated as being infested by the Rocky Mountain spotted-fever tick, where the tick is entirely absent or where it is found only occasionally.

The northern part of the Rocky Mountain region in the United States is the territory principally infested, but the river valleys and sagebrush plains to the west are more or less heavily infested. Although the spotted-fever tick occurs in the eastern edge of the Cascade Mountains, it does not appear to exist in the main Cascade range and has never been found to the west of the divide formed by those mountains. It has been found in the western portion of the Black Hills of South Dakota, and probably occurs throughout those hills. There is no doubt that the species is common in southern British Columbia and possibly eastern Alberta. Two females were collected by Dr. H. G. Dyar at Kaslo, British Columbia. This locality is about

65 miles from the United States boundary, directly north of the line between Idaho and Washington.

This tick does not seem to be limited particularly as regards life zones. It appears to be most abundant in the Transition Zone, but occurs commonly in the Canadian and Upper Sonoran Zones. It is probably also to be found in the Hudsonian Zone. Specimens have been collected at various elevations from slightly over 500 feet to

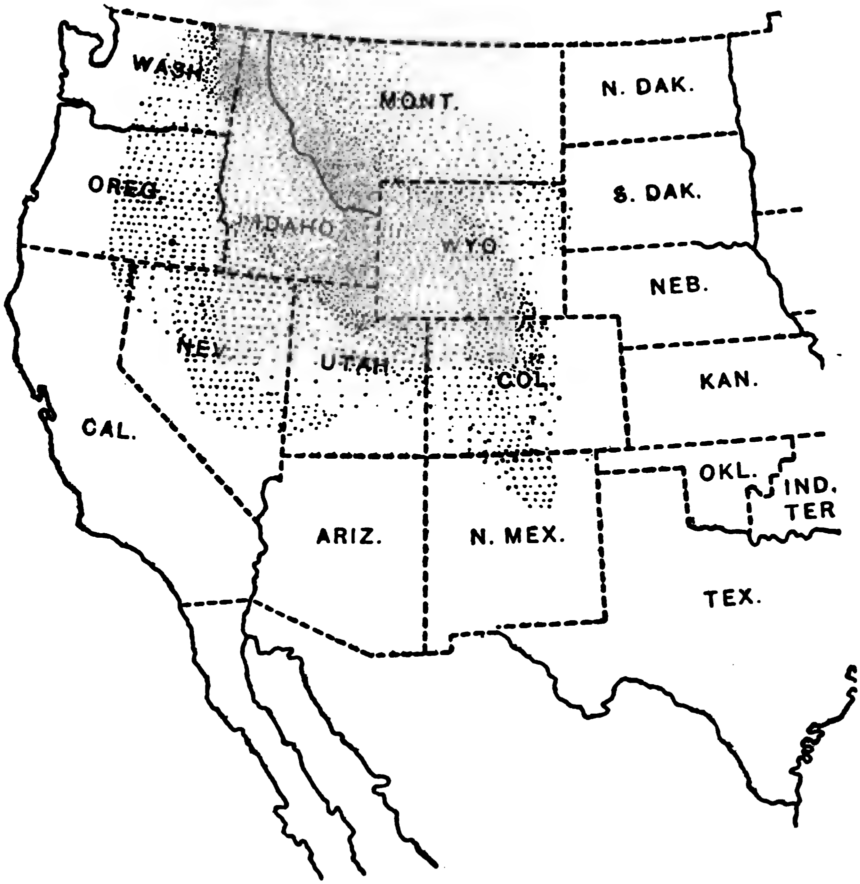


FIG. 1.—Map showing region in the United States in which the Rocky Mountain spotted-fever tick occurs. The degree of shading indicates the relative abundance of the tick in different sections. (Original.)

nearly 9,000 feet above sea level. The species seems to reach its highest development and occur in greatest numbers between 3,000 and 5,000 feet.

### FACTORS INFLUENCING ABUNDANCE.

The abundance of the Rocky Mountain spotted-fever tick is greatly influenced by the presence of numerous host animals, as well as such

protection as is afforded by timber. Ticks have been found to be especially abundant in localities where there is much fallen timber and brush. The immature ticks have been found to feed almost exclusively on the small mammals, and adults on the large domestic animals. Hence, the absence or scarcity of either of these classes of hosts greatly influences the number of ticks occurring in a given region.

Mr. Vernon Bailey, of the Bureau of Biological Survey, has pointed out that the distribution of a subgenus of the ground squirrels—namely, Colobotis—corresponds very closely to the area in which the spotted-fever tick occurs. The relation between the tick and its hosts, as well as control measures, will be discussed at length in a publication to be issued under the auspices of the Bureau of Entomology, the Biological Survey, and the Montana Agricultural College.

## THE IMPORTANCE OF THE DISTRIBUTION OF THE TICK.

It is not desired to cause undue alarm regarding the danger from Rocky Mountain spotted fever. Since, however, the malady is known to occur in a number of the States where this species of tick is found, and there is reason to believe that the disease is spreading, a knowledge of the range of the species is important. In fact there is good reason to suppose that Rocky Mountain spotted fever may occur and be transmitted to man in any region where this species of tick is present if the disease is once introduced into a locality by a tick from a disease-infected region, or by man or some other animal susceptible to the disease. It may also be stated that the tick is of some importance as a parasite of live stock. These considerations make it imperative that the tick be kept under control in all regions where it occurs and that steps be taken to lessen the danger of the introduction of disease-infected ticks into uninfected regions.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., *February 15, 1911.*

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L. O. HOWARD, Entomologist and Chief of Bureau.

# THE ALFALFA WEEVIL.

BY

F. M. WEBSTER,

*In Charge of Cereal and Forage Insect Investigations.*

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# United States Department of Agriculture,

## BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

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# THE ALFALFA WEEVIL.

(*Phytonomus murinus* Fab.)

By F. M. WEBSTER.

*In Charge of Cereal and Forage Insect Investigations.*

### INTRODUCTION.

The alfalfa weevil (*Phytonomus murinus* Fab.) is not native to America, but has been accidentally introduced from Europe, western Asia, or northern Africa, where it is common, and where, while more or less destructive to alfalfa, it is probably prevented by its natural enemies from working serious and widespread ravages. Just where or in what manner it was brought to this country no one knows, but it was first discovered in the spring of 1904 in a small field of alfalfa near Salt Lake City, Utah, and attention promptly called to its presence there by the entomologist of the Utah Agricultural Experiment Station.[a]

FIG. 1.—The alfalfa weevil (*Phytonomus murinus*): Adults clustering on and attacking sprig of alfalfa. About natural size. (Original.)

### THE FULLY DEVELOPED INSECT.

The beetle itself (fig. 1) is usually less than one-fourth of an inch in length, varying from one-eighth to three-sixteenths inch, and when freshly emerged from the cocoon (fig. 5, much enlarged), within which it passes from the larva (fig. 6, much enlarged) to the pupa (fig.

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[a] Utah Agricultural College Experiment Station, Bulletin 110. The Alfalfa Leaf-weevil, by E. G. Titus, Logan, Utah, September, 1910.

7, much enlarged), is of a plain brown color. In a few days this brown becomes darker, mixed with black and gray hairs, which give it a spotted or mottled appearance, as shown, much enlarged, in figure 3. Gradually these scales and hairs become rubbed off, so that in spring we frequently observe individuals that appear almost entirely black, with small, irregular gray spots upon them.

FIG. 2.—The alfalfa weevil: Larvæ attacking a sprig of alfalfa. Natural size; larva at right much enlarged. (Original.)

### WHERE IT WINTERS.

The insect winters entirely in the beetle stage, seeking shelter, before the frosts of autumn commerce, either in the crowns of alfalfa plants, close to the surface of the ground in the field, or under leaves, matted grass, weeds, and rubbish along ditch banks, haystacks, and strawstacks. Indeed, it is oftentimes found in barns where the hay is kept over winter. When this hay is being put into the barn in late summer, one side of the barn has been observed to be almost covered with adults, and in winter and spring, when the hay is being fed out, the floor of the barn will often be swarming with the beetles, like ants about an ant hill. It has been estimated that fully 80 per cent of the beetles that go into winter quarters in the fall live through until spring. With the coming of spring the beetles make their way forth from their hiding places and attack the young growth of alfalfa as soon as there is sufficient food for them. In ordinary seasons they may be expected to appear the latter part of March, and the egg-laying period usually lasts from early April until early July.

FIG. 3.—The alfalfa weevil: Adult. Much enlarged. (Original.)

### WHERE THE EGGS ARE LAID.

In very early spring, before the plants have made much growth, the beetles often push their eggs down between the leaves, the usual place of oviposition, however, being in punctures made in the stem (fig. 2), and some damage occurs at the very beginning of the season on account of the beetles puncturing the young stems and

killing them in their efforts to oviposit in them. Some idea of the abundance of these eggs and the extent to which the pest may breed in vacant lots and other waste lands where alfalfa has escaped from cultivation and grows as a weed may be obtained from the fact that in one case a single plant has been found to contain 127 of these egg punctures in the midst of the egg-laying season, with the punctures fresh and new. As one puncture may contain anywhere from a few to over 30 eggs, probably 10 or 15 on the average, this single plant presumably contained between 1,200 and 1,300 eggs at the time it was observed. If these hatched and half of them developed into female beetles and 80 per cent of the latter passed the winter, this plant might in a year give rise to over 150,000 beetles.

FIG. 4.—The alfalfa weevil: Eggs. Greatly enlarged. (Original.)

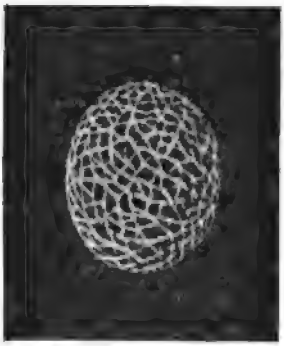

FIG. 5.—The alfalfa weevil: Cocoon. Much enlarged. (Original.)

## THE YOUNG.

Most of these eggs (fig. 4, greatly enlarged) hatch in about 10 days after being deposited, and the minute young, almost white in color, make their way to the leaves, first eating holes therein, soon assume a decidedly green color, and when full grown are about one-fourth of an inch long, with a white stripe along the back and the somewhat hooked appearance shown by some of those in the illustration (fig. 2). The attack is now confined to the young leaves and the crown of the plant, thus preventing its growth, and a badly infested field of alfalfa will frequently attain no greater height than about 6 inches, too short to mow at all. If the field is mown over most of the larvæ will of course be shaken off and drop to the surface of the ground. While some of these perish, those that survive and live upon the fresh growth, together with those hatching from eggs deposited after the mowing, develop sufficient numbers to overwhelm and destroy the second crop. The larvæ continue to attack the plants, being most abundant during May and gradually becoming less abundant throughout the month of June. As these transform, the adults become more and more abundant as the season advances, and not only do they feed upon the fresh growth, but they also eat the bark from the stems, and thus, where excessively abundant, totally destroy the

FIG. 6.—The alfalfa weevil: Larva. Much enlarged. (Original.)

second crop. Eggs have, however, been found as late as October 31 and larvæ as late as the middle of November.

The entire life of the insect, from the deposition of the egg to the emergence of the adult, may be anywhere from 40 to 70 days, while the beetle itself may live, including the winter, from 10 to 14 months.

In the first four years following its discovery the alfalfa weevil has spread over a total area of fully 100 square miles of territory. (See map, fig. 8.) So rapid has been its diffusion and so destructive its effects upon alfalfa that in the fall of 1909 the governor of Utah appealed to the Secretary of Agriculture for help in the investigation of the pest and in experimentation, with the hope of finding some measures of relief. At the present time it is known to occur from Salt Lake City southward as far as Provo and northward probably to Ogden, as it has been found within a few miles of that city. It occurs westward to Tooele and eastward, at any rate, as far as Echo City. It will not be at all surprising if by another spring it is found in southwestern Wyoming, southern Idaho, Nevada, and perhaps Colorado. The beetles have been repeatedly observed in cars on railway trains passing in and out of Salt Lake City. In one instance 27 were taken in the vestibule of one sleeping car on a train in Salt Lake City one day in July of last year, and have been found on freight cars within sight of the Idaho line. There does not appear to be any reason why it may not be carried in the same way over the San Pedro, Los Angeles and Salt Lake Railroad and left in the alfalfa fields of southern California, while by similar modes of distribution it may be carried by the Oregon Short Line Railroad into Idaho and by the Union Pacific Railroad eastward into the alfalfa fields of Wyoming and Colorado. (See fig. 9.) It is within the range of probabilities that it may find an eastern outlet over the Denver and Rio Grande Railroad into southern Colorado and western Kansas. When we come to take into consideration the fact that alfalfa escapes from cultivation, and in many cases grows as a weed along these railways and roadsides, we can well understand how easily these insects might be transported by the railways and, losing their hold, drop off along the way and find ample food in this alfalfa that has escaped from cultivation.

FIG. 7.—The alfalfa weevil: Pupa. Greatly enlarged. (Original.)

Besides railways, there is another possible means of dispersion. The beetles may, like those of some of the eastern species, be washed into the tributaries of streams and, floating down, become established in alfalfa fields along their borders. (See fig. 8.)

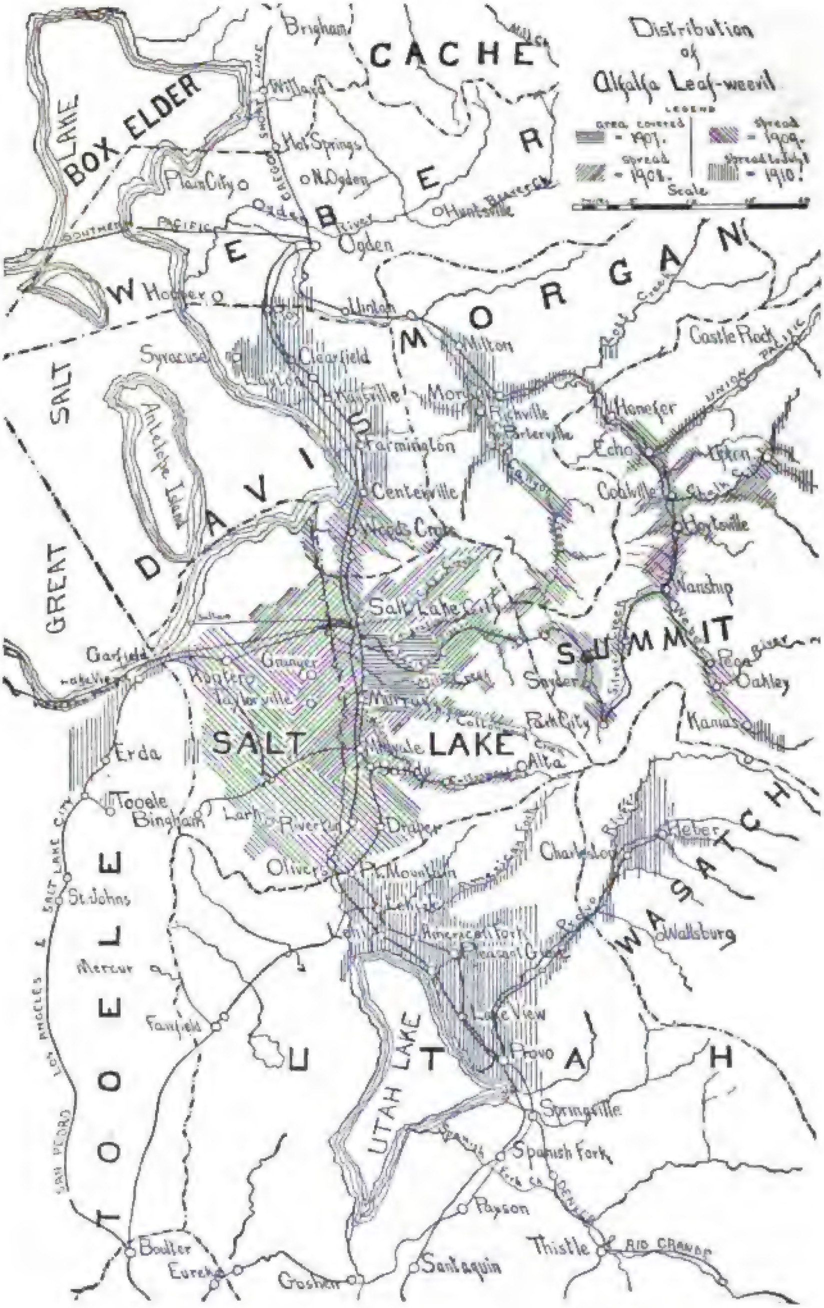


FIG. 8.—Map showing spread and area covered by the alfalfa weevil in Utah up to July 1, 1911. (From Titus.)

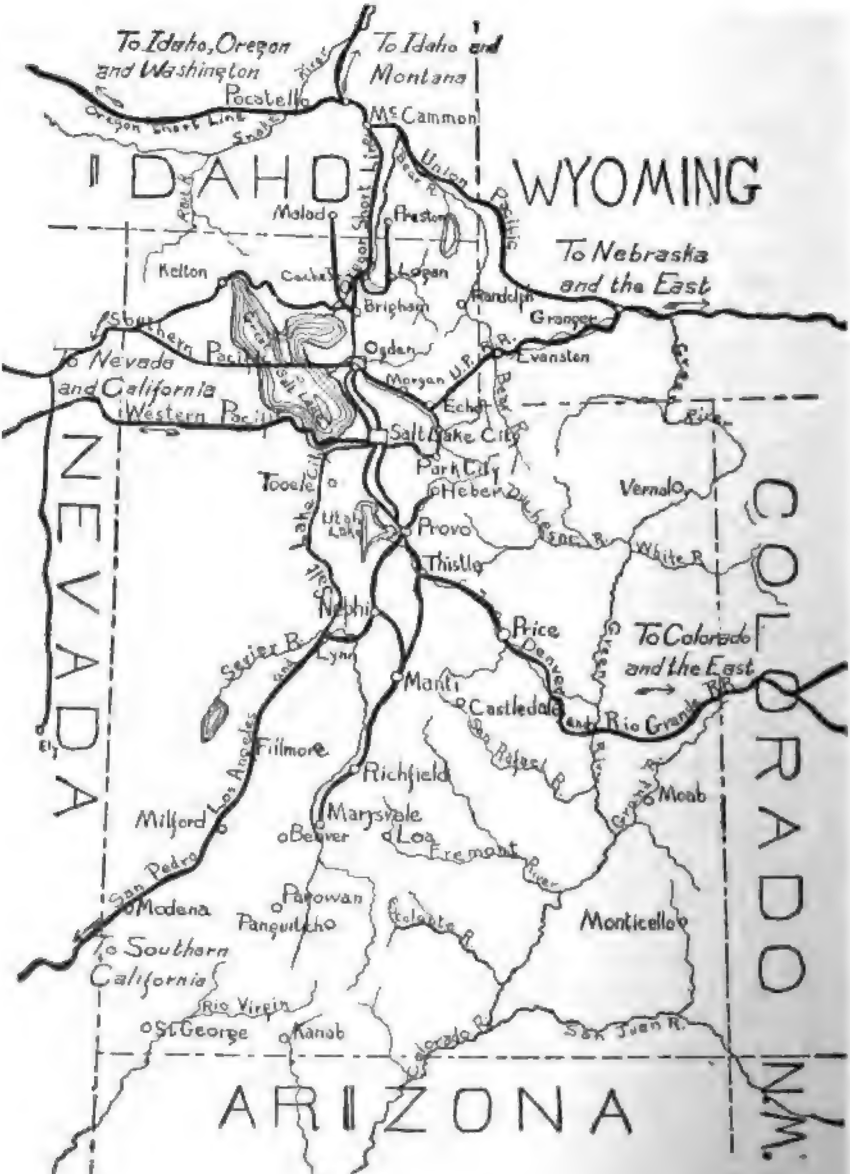


**Fig. 9.—Map showing principal railroad lines in Utah. Note: The four main lines all pass through the region infested by the alfalfa weevil. (From Titus.)**

Besides the two modes of diffusion previously mentioned (that is, by rail and by water), there is a third, which, while perhaps not disseminating the insect so far in any given time, is certainly a method of dispersion of the greatest importance. This is the migration of the adult insects, which occurs from about the middle to the 20th of June in the vicinity of Salt Lake City, after nearly all of the larvæ or worms have developed to adults. About this time great numbers of the insect seem to take wing and scatter from the fields where they have originated, being aided and their course shaped by every strong wind or gale that happens to occur at this time. As illustrating the importance of this habit of the beetles, on June 18, 1910, with a strong wind from the south, both the Government and station entomologists observed the air to be full of adults moving with the wind. Just how high these insects fly would of course indicate whether they can be carried by air currents over the mountain ranges or whether they must follow up and down the canyons. This, as well as the question as to how far they can fly with the aid of the wind, is a matter that has not yet been definitely determined. As a matter of course, the dispersion of the insect occurs almost entirely in the adult stage. Larvæ can only be carried in numbers from one field to another by the flowing water in the irrigation ditches that runs through or beside fields badly infested with the pest. They have been found floating along with the current in this way.

It must not be inferred from what has been said of this migration that all of the beetles leave the alfalfa fields in summer. It seems that these voyagers constitute only what might be termed the overflow. Vast numbers remain in the alfalfa fields, and while they do not eat the crown of the plant, as do the larvæ or young, they gnaw off and devour the outer surface of the stem, thus skeletonizing and killing the plants, giving a field thus attacked much the appearance of having been scorched by fire. If at this time a field is mown off, or when the plants have all been destroyed, leaving no more food for them, the remainder move out of the field, evidently seeking new food supply.

## FUTURE INVESTIGATIONS.

As will be observed from a study of the map (fig. 10), the pest has become established in the midst of the alfalfa region of the West, where this is by far the most important crop grown. From what is known of the insect in Europe, and in the light of its behavior since its discovery in this country, there seems little hope for anything from it but dispersion and destruction. It has no natural enemies except frogs and toads, both of which are by far too few in numbers to restrict its ravages to the slightest degree.

The Utah Agricultural Experiment Station during the season of 1910 carried out a great number of field experiments with different methods of controlling the weevil, but none of these has so far given entirely satisfactory results. Besides, measures that are practicable in one locality may be impracticable in another.

It would seem, therefore, that the efforts of the Bureau of Entomology should be, first, to endeavor to restrict the pest as effectually

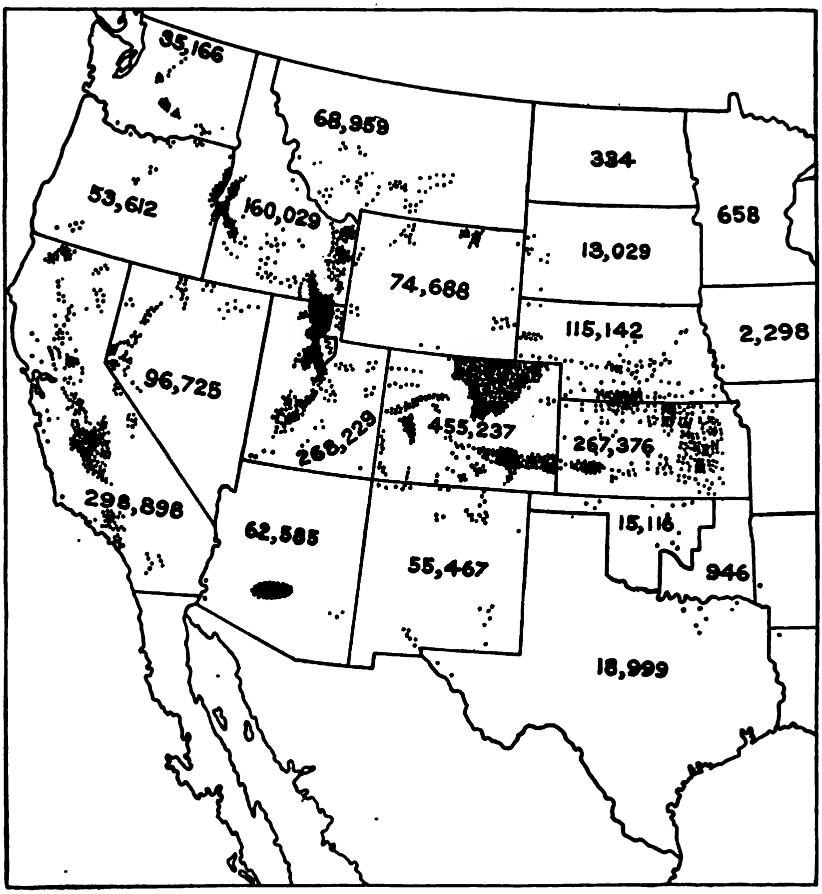


FIG. 10.—Map showing area in Utah infested by the alfalfa weevil with reference to alfalfa culture in the western half of the United States in the year 1899. Note: The numerals indicate the acreage devoted to the culture of alfalfa in each State. (From Westgate, Farmers' Bul. 339.)

and as long as possible to its present area of infestation, and, second, to use every means in its power to control it, in the meantime, within this area. In the first instance, the bureau experts will have the cooperation of the Utah Agricultural Experiment Station, as during the past year (1910), but in the very important part of this work, namely, the introduction and colonization of natural enemies, both

native and foreign, the Federal authorities can treat the infested section as a whole, regardless of State boundaries, and thus work without handicap.

Quarantine between the different States is, in the case of the alfalfa weevil, wholly useless on account of the agency of the railroads and winds as factors in the dispersion of the beetles. There is danger of dispersion in shipments in interstate commerce, but in the case of what is perhaps the most dangerous medium, that of baled hay, owing to the ravages of the pest, the movements of shipments are fortunately toward instead of from the infested area. As to other articles entering into interstate commerce, it would be impossible to guard against the beetles concealing themselves in almost any sort of a box, bale, or package of whatever shape, size, or nature.

The most inexpensive and practical means of controlling introductions of the pest by railroads appears to be in the close surveillance of the railroad right of way and the stamping out of incipient outbreaks as soon as discovered. This, too, seems a duty likely, at least for the present, to devolve upon the Federal authorities, as nearly all of the States adjoining Utah are without the means of carrying such a plan into operation, and a year at least would be required to put into operation the legislative measures necessary to meet the situation. Therefore, the greatest assistance can be afforded by the growers of alfalfa personally, especially along railways and near towns and villages, by keeping close watch of their fields and promptly notifying the Government or State authorities of the occurrence of any insect resembling this alfalfa weevil, as described and illustrated herein. It is chiefly for the purpose of reaching such persons and of promptly obtaining information as to the first appearance of the pest in any locality that this circular is published.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *February 25, 1911.*

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